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RHINOMANOMETRY IN SOME RHINOLOGIC DISEASES.

JOSEPH H. OGURA, M.D.,*
and
POUL STOKSTEAD, M.D.†
St. Louis, Mo.

The function of the nasal passages during respiration can be determined by rhinomanometry, a method of measuring pressure variations within the nasal cavity. Courtade[1] described pressure variations obtained from the right and left nostril by means of a simple U-shaped water manometer attached to a nasal plug. His method gave a very rough idea about the passages of the nasal cavities since his liquid manometer was capable of indicating only the maximum and minimum pressure in the rhinopharynx. The disadvantage of his method was that values obtained were dependent upon the respiration rate and provided no possibility of estimating the pressure during respiration through both nasal cavities.

The great advantage of the Courtade method was the use of simple equipment and easy applicability to the patient. One of us (P.S.[2]) has improved the method by replacing the liquid manometer with a recording diaphragm-type manometer that is capable of integrating as well as recording the pressure variations during each phase of respiration. The manometer

*Department of Otolaryngology, Washington University School of Medicine, St. Louis, Mo.

†From the Department of Ear, Nose and Throat Disease, University of Copenhagen, Denmark. (Chief: Prof. H. K. Kristensen, M.D.); Visiting Fellow in Otolaryngology, Washington University School of Medicine, St. Louis, Mo.

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is connected with an amplifying unit provided with two ratemeters, which add up the inspiration and expiration pressures respectively. The ratemeters are monitored by a timer which starts and stops the ratemeters at a previously stipulated time of one minute. A recorder which registers the pressure curves and the respiratory rate per minute is attached to the rhinomanometer.

From the recorded values it is possible to calculate the resistance during inspiration and expiration through the right and left nasal cavity and by means of a formula to calculate the total resistance of the nose during free respiration through both nasal cavities.

Long practice has demonstrated that it is most convenient to measure the resistance in the right and left nasal cavities at intervals of half an hour, and to follow the deflections of the resistance for a period of 45 minutes. To give a comprehensive view of the mutual proportions between the resistance of the right and left side together with the total resistance, the obtained values are plotted in a coordinate system in which the time is plotted along the abscissa and the resistance along the ordinate.

In the last two years we have been able to make about 350 tests from normal persons and from patients suffering from various nasal diseases. Fairly good impressions of the normal rhinometrical curves and curves typical for the nasal diseases in question have been obtained. Unfortunately, most people will have more or less deviated septa or asymmetrical development of the turbinates. This will result in obtaining curves of a mixed type.

THE NORMAL NOSE.

The ideal nose has a relatively uniform calibrated slit-shaped nasal cavity, ½-mm. wide at its narrowest point with the septum. The regular alternating movements of the turbinates adjust in such a way that the total lumen or resistance during the inspiration and expiration is kept at a constant level. Few normal noses will comply with the mentioned demands due to deviations of the septum, spurs and cristae

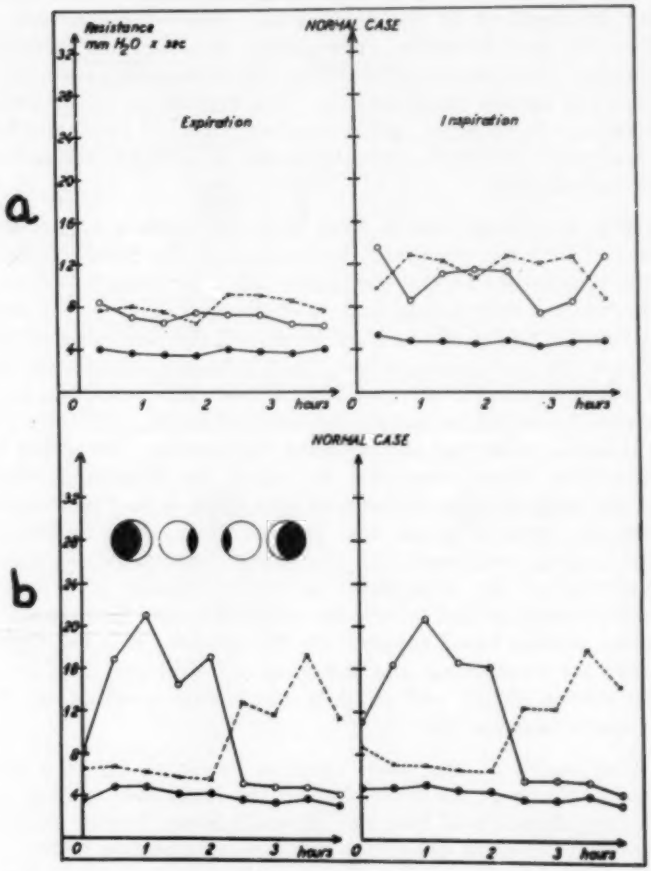


Fig. 1. Inspiration and expiration curves from two normal persons with normal deflections of the turbinates and normal resistance in the nasal cavities: o - o - o - o Resistance in the right nasal cavity; x - x - x - x Resistance in the left nasal cavity; ● - ● - ● - ● Calculated resistance of the entire nose (Total resistance).

The curves in Fig. 1-a are from a person with very high and narrow nasal cavities, while Fig. 1-b shows curves from a person with ample space in the cavities and large, prominent turbinates. The "black moons" indicate the engorgement of the turbinates with corresponding narrowing of the airway, and the associated open airway on the opposite side of the nose with constricted turbinates.

when one considers these anatomical deformities with irregular development of the turbinates. The curves shown in Fig. 1-a are, however, approaching the "normal" circumstances. The curves are obtained from a normal person with high and narrow nasal cavities. The deflections of the turbinates are fairly small and the curves from the right and left nasal cavity intersect irregularly due to a slight contraction of the left side.

Fig. 1-b shows curves from a person with a broad, low nose with large prominent turbinates in the nasal cavities. The movements of the turbinates are very pronounced and alternate in such a way that the total resistance in the nose is kept on an almost constant level. At the beginning of the curves the turbinates on the right side are constricted but increase rapidly to the peak of dilation and reach the next phase of contraction in two and one-half hours, while the left turbinates undertake the opposite movements. According to Heetderks[3] these movements are called the physiologic cycle of the nose, and the purpose of this cycle is to moisten and heat the respiratory air and prevent drying and cooling of the mucous membranes in the lower respiratory passages. Warming of the respiratory air occurs mainly in the contracted nasal cavity, where the turbinates are dilated owing to the copious blood supply. On the opposite side the turbinates are contracting and throwing off thin secretion from the serous glands and in this way create a situation for adequate evaporation.

The length of the nasal cycle is measured between two similar phases of the movements of the turbinates and has an average duration of two and one-half hours, but in normal cases usually show variations between one and five hours.

COMPENSATORY HYPERTROPHY OF THE TURBINATES.

In instances where significant differences between the lumina on the right and left side exist, the turbinates in the wider side will hypertrophy for the purpose of filling this cavity. This hypertrophy is usually explained as the effort of the body to compensate for this deformity. Fig. 2 illustrates such a case, where the left nasal cavity is considerably

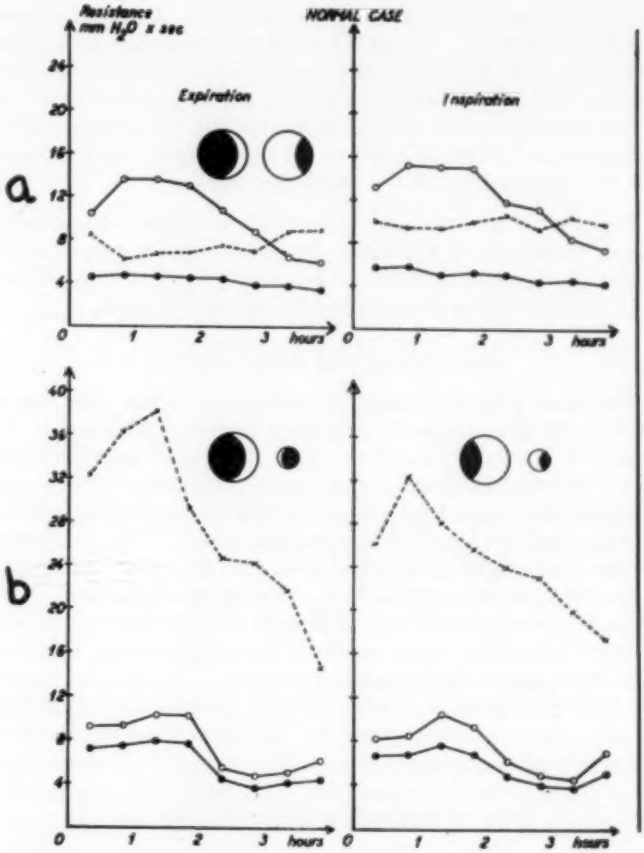


Fig. 2-a. Rhinometric curves from a person with normal alternating movements of the turbinates.

Fig. 2-b. Inspiration and expiration curves from a patient showing pronounced contraction of the left nasal cavity and with ample space and hypertrophy of the turbinates on the right side. The movements of the turbinates are synchronous.

contracted, while the right side has ample space and large prominent turbinates. The left side is narrowed to such a degree that it contributes only slightly to the air passage, and the right nasal cavity is the main conductor of the air current during respiration. For this reason the resistance curve from the right side and from the entire nose will show parallel courses rising and falling according to the movements of the right turbinates. In several instances the turbinates showed synchronous instead of alternating movements, which accelerate the fluctuations of the resistance curves.

Patients of this category will usually complain of stuffiness in the wider side of the nose. Diagnostic errors can be easily made, for inspection of the wider nasal cavity usually reveals that the turbinates are small and appear shrunken.

DEVIATION OF THE NASAL SEPTUM.

The most frequent cause of alteration in the rhinometric curves are deviations of the nasal septum. Generally, one side will show an almost normal space and normal cyclic curve, but the contracted nasal cavity will show pronounced irregularities caused by contact of the turbinates against the septum during a part of the dilating phase. Fig. 3-a shows a case of a marked septum deviation with the spine and septum projecting into the left nostril. During the dilatation of the turbinates the left side is almost shut off, but during the contraction phase the nasal cavity will open suddenly resulting in a short period of decreasing resistance. In the case shown, the total resistance is so high that the patient has to undergo reconstruction of the septum for the purpose of re-establishing a normal airway.

VASOMOTOR RHINITIS.

By rhinometric examination of a normal nose with the surrounding atmosphere kept at a constant temperature and humidity, we have observed alternating movements of the turbinates. On one side of the nose the turbinates contract and throw off thin secretion from the serous glands, while the turbinates on the other side dilate with engorgement of the vascular system for the purpose of heating the inspiratory

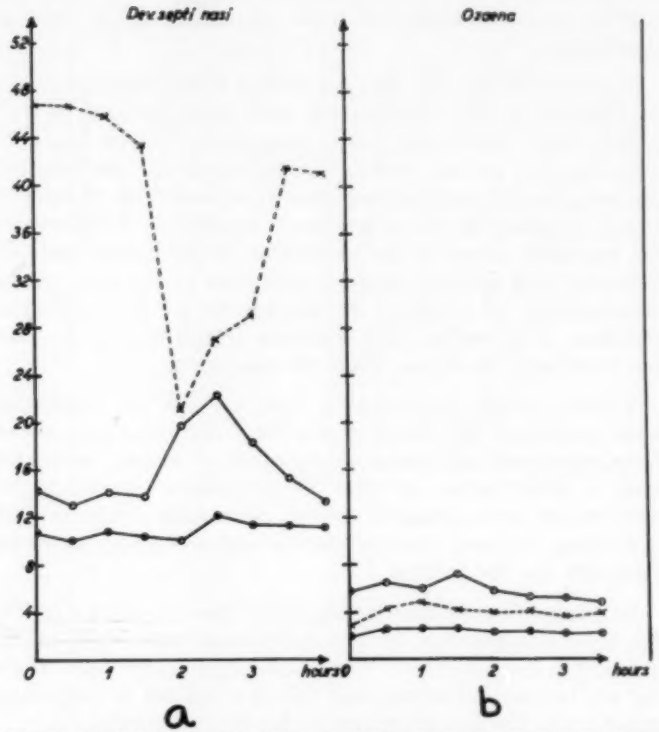


Fig. 3. Resistance curves during expiration from a patient with septum deviation to the left (3-a), and from a patient suffering from ozena (3-b).

air current. The movements are connected with alternating changes in the lumina of the nasal cavities in such a way that the computed lumen of the nose is kept at the same level.

Physical factors such as variations of temperature and humidity cause the turbinates to respond with synchronous movements and contract or dilate at the same time in both nasal cavities in order to prepare the air for the lung.[3] The deflections caused by the synchronous movements are generally so pronounced that they almost cover the alternating

movements, which will first appear again when the nasal cavities have accomplished their adaptation to the new atmosphere.

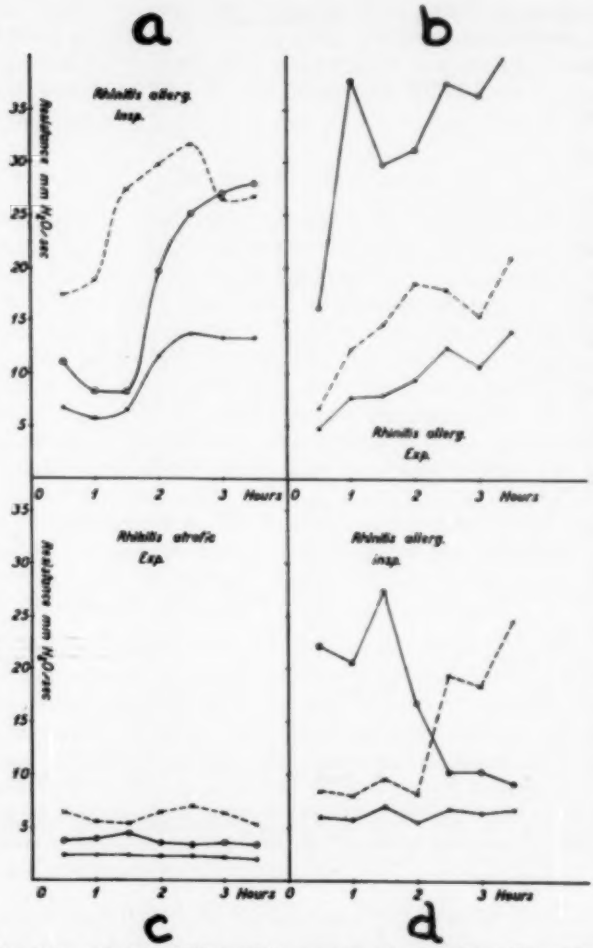
In a normal nose the changes elicited in the vascular system by changes of the temperature and humidity will be kept within such limits that there remains sufficient space for adequate respiration; but in vasomotor rhinitis the reactions are exaggerated, and the responses arise even with abnormally small variations in the atmospheric condition. Furthermore, the engorged phase of the turbinates is maintained over abnormally long periods, causing stuffiness of the nose and an accumulation of secretion in the glands of the turbinates, resulting in a profuse thin secretion from the nostrils when the turbinates reach the stage of relaxation.

Typical curves are shown in Figs. 4-a and 4-b in patients with vasomotor and allergic rhinitis. The resistance curves from right and left nasal cavity start at normal level, but after a short period of time the turbinates respond to the temperature and humidity of the laboratory, which results in a steady increase in resistance on both sides, and breathing difficulty for the patient.

In a few cases we have seen another curve as shown in Fig. 4-d with exaggeration of the alternating deflections of the turbinates, and sometimes with acceleration of the nasal cycle. We are inclined to believe that this is a variant of vasomotor rhinitis, but the investigations so far are not conclusive.

OZENA AND ATROPHIC RHINITIS.

Before testing the patients suffering from ozena it has been necessary to remove crusts from the nasal cavities with irrigations of saline solutions. Crusts obtained from ozena patients are identical with the diagram shown in Fig. 4-c, with extreme low values indicating complete lack of movement of the turbinates. Extensive chronic inflammation and atrophy of the turbinates have affected their ability to influence the air currents during inspiration and expiration. In a few instances normal or slightly increased resistances are observed in one or both cavities due to a narrowing of the internal *os*,



Figs. 4-a and 4-b. Rhinometric curves of patients with vasomotor rhinitis. The abrupt rise in the resistance are caused by synchronous movements of the turbinates.

Fig. 4-c. Atrophic rhinitis with very small deflections of the turbinates and a diminutive cycle of the nose.

Fig. 4-d. Vasomotor rhinitis with exaggeration of the alternating movements of the turbinates.

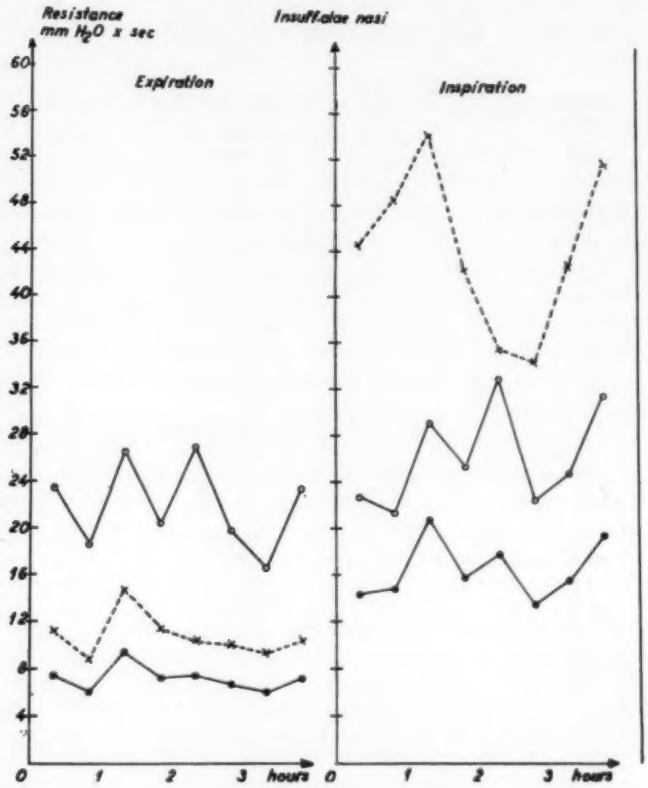


Fig. 5. Rhinometric curves during inspiration and expiration in a case of collapsing alae nasi. The obstruction is most pronounced on the left side, which has normal resistance during expiration but a pronounced increase of resistance during inspiration.

that portion between the vestibule and the nasal cavity proper, despite the atrophy and reduced excursion of the turbinates. With such small and low pressure deflections in atrophic rhinitis it is almost possible to identify the movements of the turbinates and a diminished cycle of the nose.

In a normal patient the turbinates will show a very pronounced engorgement, resulting in complete obstruction of the

nasal cavity in question if the stellate ganglion is blocked; however, in atrophic rhinitis since the vascularity is reduced there is a very incomplete response to the stellate ganglion block, and the dilation will disappear much faster than in normal cases.

COLLAPSING NASAL ALAE.

During each moderate respiration the nasal alae move outwards like a pair of floodgates,[4] thereby dilating the internal *os* and reducing the resistance during the inspiration phase to such an extent that both respiration phases are kept at almost the same resistance level, despite the fact that the inspiration phase lasts a somewhat shorter time than the expiration. The movements of the alae are controlled by the levator alae muscles and increase in magnitude by forced respiration. The contractions of the muscles occur just before the inspiration begins and continue during the whole inspiratory phase, while the muscles relax during the expiration. The activity of the muscles was demonstrated by Van Dishoeck,[5] who was able to detect action potentials from the muscles. The movements depend upon a reflex arc, which has its efferent pathway via the facial nerve.

Collapsing nasal alae are observed in patients with high, long and narrow noses, and is due to the disturbed anatomical relationship of the upper lateral and alar cartilages to the septum, and in some instances with paralysis of the facial nerve. The high and elongated septum is associated with the narrowing of the caudal end of the upper lateral cartilage relationship to the septum. This effectively reduces the size of the internal *os* and collapses the nasal alae upon moderate forced inspiration.

Usually there are differences in the degree of insufficiency of the nasal alae on the two sides, and this must be considered in naasl reconstruction for the purpose of obtaining satisfactory ventilation of both nasal cavities.

RELATIONS BETWEEN THE NOSE AND LUNGS.

Recently we have tried to establish a relationship between

the nose and the lung. Few studies have been made on efforts to measure pulmonary function together with the nose. In this respiratory test, one measures the ability of the lung to expire through the nose against a calibrated resistance. An inflatable rubber mask is fixed tightly to the head by means of rubber ribbons and is provided with a calibrated valve.[2] In beginning the test, the diaphragm of the valve is adjusted to an opening that does not interfere with the respiration of the patient. The valve is later closed in steps, at five minute intervals up to the valve opening, which allows the patient just a sufficient supply of air. The respiratory resistances arising in the mask during the test are measured by the rhinomanometer unit and the respiration rates are registered at every step by which the valve is closed.

Most normal people are able to breathe against a resistance ranging from 80 to 100 mm. H_2O x sec., which is about 20 to 25 times as much as the normal resistance of the nose. In some apparently normal cases we have seen much lower values, which is in conformance with the investigation of McKillick,[5] who found 20 to 30 per cent of lowered pulmonary function among normal persons.

In a few mouth-breathing patients with this respiratory test, we have been able to detect very low resistance values, due to a decreased ability of the lungs to respirate against the normal resistance of the nose. Many of these cases have shown, at the same time, decreased nasal resistance with an almost normal proportion between this respiratory test and nasal airways. For this reason these patients have maintained their normal respiration through the nose.

DISCUSSION.

Much information has been obtained about the configuration of curves typical in normal patients and in certain nasal diseases. We have obtained typical curves in cases of vasomotor rhinitis, septum deflections and collapse of the nasal alae, and we have been able to determine the degree of each factor involved. Obviously this is of importance from the therapeutic point of view. A correction of the septum, the abolition of the collapsing nasal alae would be of value to the

patient when the vasomotor component is not too pronounced. The exaggeration of the alternating movements of the turbinates and the acceleration of the nasal cycle will be evident in vasomotor rhinitis.

In other cases we have found a normal nasal airway despite the severe complaints of nasal discomfort. Most of those instances are cases of nasal neurosis, or possibly an undetected pulmonary or cardiac disease of short duration. In both instances surgical intervention is not advised. Surgery would not be advised, even though obvious anatomical deformity was present. In the former instance the complaints of the patient will usually increase if surgery is performed. Often nasal complaints will disappear after appropriate treatment for pulmonary or cardiac disease.

The measurement of the ability of the patient to breathe against resistance, as measured through the nose is a respiratory test, but may not represent a true pulmonary function test. Many variables enter into this picture. The muscular strength of the chest wall, general condition of the patient, bronchial resistance, volume exchange, elasticity—the problem of lung compliance—which is not measured in this instance. The real importance of measuring the pulmonary function in connection with the rhinometric test of the nasal cavities was emphasized by Sercer[6] several years ago, but it has to some extent been neglected by later investigators. It is significant that to date no definite relationship of the nose and the lung has been established by an objective test. Nasal function test, as measured by the rhinomanometer, and the establishment of pulmonary function tests are well documented by simultaneous observations of both present major technical problems.

Clinically it is important to know whether this relationship exists. Why is it that some people with obstructive nasal airways, due to a badly traumatized nose, complain of dyspnea? The "chronic lunger" who bitterly complains about nasal obstruction; the chronic mouth breathing child often has a deformity of the chest with a pronounced flattening of the ribs. One wonders about this relationship! The adult

patient with oral respiration may have decreased ability to breathe against resistance. In such instances, it seems that attention should be directed toward improving the nasal airway surgically, and perhaps even toward proper pulmonary exercises.

Since the nose serves as a protective organ and prepares the air for the lung, it seems logical that we should look for better objective methods for testing nasal and pulmonary functions.

SUMMARY.

On the basis of about 350 rhinometric examinations of the nasal passage with resistance measuring from the right and left nasal cavity, typical resistance curves are shown from normal persons and from patients with deviations of the septum, vasomotor rhinitis, and atrophic rhinitis with ozena and collapse of the nasal alae.

The relationship between the nose and lung is discussed briefly. A method is outlined for measuring the ability of the lung to breathe against increasing resistance.

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A STUDY OF THE RELATIONSHIP OF AIR PRESSURE TO MYRINGORUPTURE.*†‡

A. PAUL KELLER, JR., M.D.,

Athens, Ga.

The aim of this study was to determine what amount of air pressure, within a closed system, directed against the human tympanic membrane would cause it to rupture.

In 1898 Lester and Gomez[33] reported the effects of compressed air on the human ear from observations made in a caisson of New East River bridge. The study was mainly concerned with the effect on hearing, but several conclusions have a bearing on this study. For example, it was stated that the hearing power for both air and bone conduction was reduced directly in proportion to the atmospheric pressure; more specifically, it was pointed out that a pressure of one-half an atmosphere caused depression of the drum membrane, and a pressure of two atmospheres caused a marked disturbance of the drum membrane with congestion of the pars flaccida and the malleolar plexus; and that when descending in the caisson, there was considerable danger of the drum membrane's rupturing unless the Eustachian tube was successfully opened voluntarily. They warned against persons with colds, chronic ear disease or labyrinthine disease entering a caisson.

In 1929 Vail[49] gave a report to the American Otological Society concerning traumatic ear conditions in workers under compressed air. His work was mainly concerned with caisson disease and its effects on the middle and inner ears. He reported two cases of rupture of the human eardrum membrane, one in a Negro man while working under a pressure of 27 lbs./in.^{2} and the other a "young" man working under a

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‡From the Dept. of Otology and Rhinolaryngology, Emory University.

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pressure of 30 lbs./in.^{2}. How closely these figures approximate those found from this study will be apparent soon.

In 1937 Armstrong and Heim[5] reported the effects of positive and negative pressure on the eardrum membrane of five apparently healthy men. They found that as atmospheric pressure decreased (as in an ascending airplane) the Eustachian tube opened automatically, first, when the pressure differential reached 15 mm. of mercury; next, when it reached 11.4 mm., until at 40,000 feet it opened at a differential of only 3.5 mm. This they attributed to a rarefaction of the air, which then passed through the Eustachian tube more easily; however, when the atmospheric pressure increased (as on the descent of an airplane) the Eustachian tube failed to open spontaneously and remained closed at all pressures unless voluntarily opened. At a differential of 60 mm. of mercury of negative pressure, pain became severe; at 60-80 mm. very severe; and at more than 80 mm. agonizing. They stated that the eardrum membrane ruptures between 100 and 500 mm. of mercury, and reported one case that ruptured at 470 mm. of mercury accompanied by a loud report, shock and severe dizziness. (It was not revealed how the figures of 100 to 500 mm. of mercury were derived, nor how many eardrum membranes were ruptured.) It was noted that when a negative pressure differential of 80 to 90 mm. of mercury developed, the muscles of the Eustachian tube could no longer voluntarily open the tube.

In 1941 Van Dishoeck[17] studied tension on the human tympanic membrane in relation to hearing and decided that any deviation from the normal tension led to hearing impairment. He used pressures up to 100 cm. of water without any reported rupture. Canfield[6] in 1944 reported results of pressure chamber experiments on the tympanic membrane, *e.g.* decompression from 7,000 feet (equivalents), and found severe retraction and aerotitis, which readily responded to myringopuncture, but he did not mention any spontaneous ruptures.

In 1942, and again in 1945, there appeared articles by H. B. Perlman[40,41] of Chicago concerning the effect of explosion and blast on the human acoustic conduction apparatus. By

attaching tiny mirrors to various parts of the conduction apparatus in fresh, human, temporal bones he was able to measure the displacement of the part under study (*e.g.*, malleus or stapes) and record its excursions under the influence of the shock pulse produced by explosions or loud sounds. He discovered that at a magnification of 200 times the malleus moves when stimulated by a sound at 50 db. above the threshold of hearing. It was mentioned in these papers that static pressure of 200 to 400 mm. of mercury would rupture the tympanic membrane, but how these figures were determined was not elucidated. Several other figures regarding the pressure developed by the shock pulse were mentioned. Since the threshold of sound perception at 1000 cycles is 10^{-16} watts/cm.^{2} it can be seen that the intensity of the shock pulse is usually many times greater than the "loudest sustained sounds" and may equal many atmospheres. For example, Perlman points out that Thompson measured the intensity of the shock pulse 26 feet from the explosion of 10 lbs. of TNT and arrived at a figure of 10^4 watts/cm.^{2} which is equal to 200 db. above the threshold of sound perception. He quotes Miller as stating that the pressure developed 12 feet in front of a 12-inch gun is 542 lbs./in.^{2} Sustained sound becomes unbearably loud at about 10^{-4} watts/cm.^{2} (or 120 db.), so it is easy to see how greatly shock pulses exceed the usual decibel intensity of sustained periodic sound. Craig[11] stated that probably the first case of traumatic perforation of a tympanic membrane by explosion to be examined and visualized by otoscopy was that seen by Gruber in 1866, three weeks after the battle of Sadowa.

In 1943 Dean[16] discussed blast injuries, and pointed out that a 70-pound charge created a pressure of 110 lbs./in.^{2} at 14 feet distance, 60 lbs./in.^{2} at 18 feet, 15 lbs./in.^{2} at 30 feet and 6 lbs./in.^{2} at 50 feet and that 100 lbs./in.^{2} is dangerous to life.

The effect of aircraft noise upon hearing was reported in 1944 by Senturia,[46] who noted that noise levels of 128 db. were reached in trainer planes and stated that this decibel intensity approaches pain level as well as causing auditory fatigue. Also in 1944 Silox[47] reported on 82 cases of blast

injury and noted that the loss of hearing was more severe when the tympanic membrane remained intact than when it ruptured. Cantor[7] in 1945 sought to explain this observation on the basis that the pulse wave enters by way of the Eustachian tube, and if the tympanic membrane remains intact the middle ear acts as a pressure chamber transmitting force to the windows of the inner ear. In 1945 Henry,[26] in discussing 292 blast injuries of the ear, failed to find any drum membranes perforated in Shrapnell's area.

Fitz-Hugh[20] in 1946 discussed traumatic perforation in 58 servicemen due to high explosives, but did not suggest what pressure was exerted on the eardrum membrane. Ireland[28] tabulated 317 cases of traumatic perforation from blast injury and concluded that high explosive and mortar fire was most often implicated, but the pressure necessary to rupture the eardrum membrane was not discussed. In 1949 McReynolds[42] was able to report on 286 ears subjected to blast injury in the Texas City disaster but no mention of rupture pressure was made. Whittingham[52] in 1954 discussed an unusual case of perforation of both eardrum membranes during anesthesia, when the patient was "hand breathed" with the bag, but the pressure exerted was not suggested and would be hard to predict. Schnurbusch[45] in 1954 described a case of unilateral perforation of the tympanic membrane in a 30-year-old construction worker who was hammering on a tin cylinder and attributed the rupture to sound trauma. There was a perforation anterior and posterior to the malleus handle associated with tinnitus and hearing loss. Within three weeks the membrane healed, and the hearing returned to practically normal. In the discussion of this case the author points out that the type of resistance offered to sound pressure by the tympanic membrane is varied. At lower frequencies the drum membrane acts like an elastic membrane, whereas at higher frequencies, say about 800 cycles, it shows a resistance more like a mass reaction to the sound pressure. Consequently, the elasticity of the drum membrane at low frequencies offers effective resistance, and considerable sound pressure is necessary to cause rupture. At higher frequencies, due to the resistance of the drum membrane in mass, much less protection is offered, and higher frequency sounds can cause

rupture with less pressure; however, higher frequency sounds are very directional, so the axis of the sound must be at right angles to the drum membrane to exert maximum effect. It can thus be seen that the main protective feature of the eardrum to low frequency sounds is its elasticity, while at higher frequencies the highly directional quality of the sound waves helps prevent sound trauma unless the axis is oriented at right angles to the drum membrane.

The lower frequency sounds would be expected to produce more bilateral perforations while the higher frequency, more directional sounds, would produce more unilateral perforations of the tympanic membrane.

A large number of discussions of blast injuries of the eardrum membranes appear in the literature, *e.g.*, Craig[11] in 1941, Alexander[1] in 1941, Dean,[16] Alexander,[2] Palmer[38] in 1943; Craig,[13] Silox,[47] Senturia[46] in 1944; Cantor,[7] Bennington,[5] Henry[26] in 1945; Korkis,[31] Ireland,[28] Fitz-Hugh[20] in 1946; Falbre[21] in 1947; Friedman,[23] Collins[10] in 1948; McReynolds,[42] Rice[43] in 1949; Garcia-Vaquero[24] in 1953; yet, insofar as it was possible to glean this material, no reference was found as to the pressure necessary to rupture the human eardrum membrane. Parenthetically, frequent reports have been made of perforations of the eardrum membrane associated with lightning injuries, and of sudden death due to drowning related to a perforation of the eardrum membrane. Obviously, these could not be concerned with pressure analyses.

Of the many available methods of rupturing the human eardrum membrane experimentally, the use of air pressure most nearly resembles the common manner in which many accidental ruptures occur, and so a method was devised whereby air under a measurable amount of pressure could be directed against the membrane in a closed system. Originally two 260 mm. sphygmomanometer tubes were sealed together, giving an effective pressure of 520 mm. of mercury, but this pressure failed to rupture either of the first two drum membranes tested. This method was discarded. Then, a hand-pumped air pressure tank was attached to a metal handpiece, with one pressure gauge at the tank and another

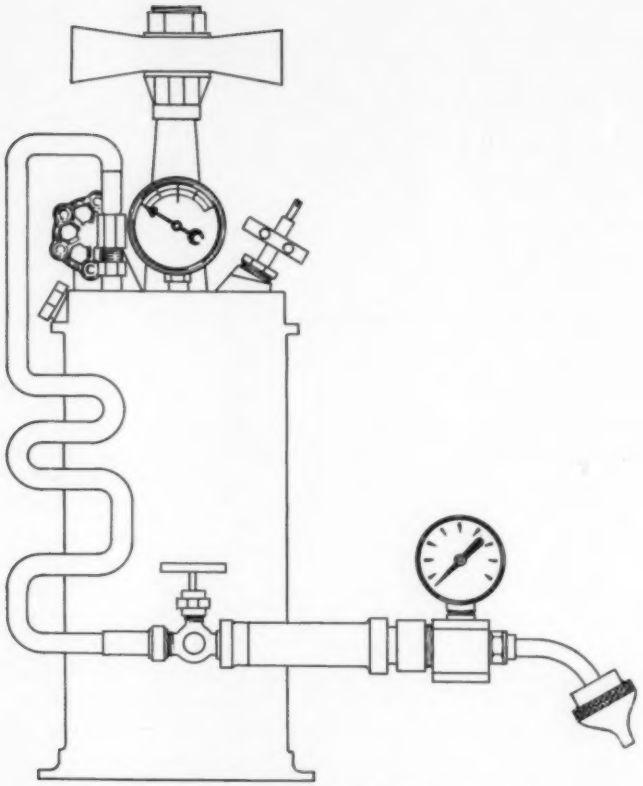

Fig. 1. Drawing of Apparatus Utilized.

at the hand piece, which was inserted into the external auditory canal. A tightly fitting earpiece connected the pressure apparatus to the external auditory canal and transmitted the air pressure to the outer surface of the tympanic membrane (see Drawing). This was used for most of the work, but the hand-pump was later supplanted by a tank of compressed air, which was easier to transport and utilize.

With such an apparatus air was directed against the outer

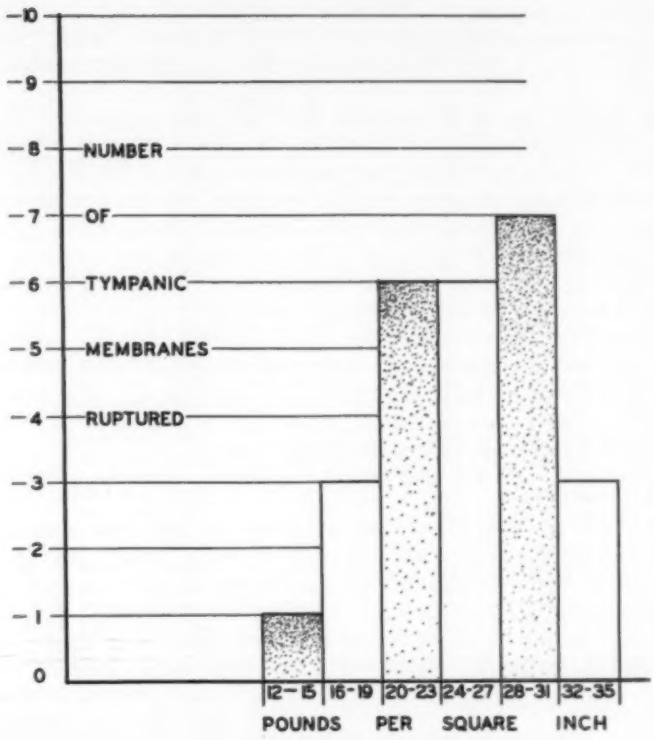

Chart 1.

surface of the tympanic membrane of recently deceased human beings under a variety of conditions. First, gradually increasing pressure was utilized until rupture occurred; then suddenly applied pressure was utilized, increasing the pressure with each application until rupture occurred; finally, in order to be sure that the pressure being measured was actually that required to rupture the eardrum membrane, and not also that necessary to open the Eustachian tube, the tegmen tympani was exposed and an opening made through this structure into the middle ear so that only the eardrum membrane opposed the air pressure.

TABLE OF CASES.

Age		Pressure (lbs./in.²)	Results	Location Point
51	AD	10	No perf.	
	AS	10	No perf.	
26	AD (S)*	28	Perf.	Not visualized.
	AS (S)	31	Perf.	Ant. inf. pars tensa.
28	AD (G)†	25	Perf.	Ant. to malleus handle.
	AS (G)	20.5	Perf.	Ant. sup. pars tensa.
59	AD (G)	20	Perf.	Ant. sup. pars tensa.
	AS (S)	25	Perf.	Post. pars flaccida.
49	AD (G)	21	Perf.	Ant. sup. pars tensa.
	AS (S)	23	Perf.	Ant. pars tensa.
39	AD (G)	18	Perf.	Post. pars tensa.
	AS (G)	33	Perf.	Ant. inf. pars tensa.
50	AD (G)	40	No perf.	Technical difficulty.
	AS (G)	31	Perf.	Pars flaccida.
25	AD (G)	33	Perf.	Ant. sup. pars tensa.
	AS (S)	26	Perf.	Ant. inf. pars tensa.
65	AD (S)	16	Perf.	Post. pars tensa.
	AS (S)	14	Perf.	Post. pars tensa.
Not	AD (G)	22	Perf.	Post. pars tensa.
Known	AS (S)	20	Perf.	Post. pars tensa.
Not	AD (G)	18	Perf.	Ant. pars tensa.
Known	AS	Ruptured by instrumentation		(tegmental opening).
27	AD (S)	34	Perf.	Ant. pars tensa.
	AS (G)	30	Perf.	Ant. pars tensa. (tegmental opening).
52	AD (G)	28	Perf.	Post inf. pars tensa.
	AS (G)	30	Perf.	Post inf. pars tensa.
83	AD (S)	24	Perf.	Ant. inf. pars tensa.
	AS (G)	30	Perf.	Ant. inf. pars tensa.
2	AD (G)	24	Perf.	Ant. inf. pars tensa.
Weeks	AS (G)	24	Perf.	Not found.

*Sudden. †Gradual.

The number of subjects tested was 15. The ages of the subjects at the time of death varied from two weeks to 83 years. Four subjects were Negro, the remainder white. Thirty eardrum membranes were examined by one of the above methods: four did not rupture, either because of insufficient pressure (original attempts) or because of mechanical difficulties. Of the eardrum membranes which did rupture the following observations were possible (see Chart 1). The lowest pressure at which any ruptured was 14 lbs./in.² The highest pressure required to rupture any in the series was 33 lbs./in.² The mean breaking pressure was 25 lbs./in.² The right eardrum membranes ruptured at an average pressure of 24 lbs./in.², and the left eardrum membranes at an average pressure of 26 lbs./in.² There was no significant

difference between rupture pressures when gradual or sudden application was made. Individual cases are presented with comments concerning each (see Table).

It is realized that the first question to be raised may be whether or not the eardrum membrane of a dead human being has the tensile strength of that of a live person. In the living human being the stapedial and tensor tympani reflexes could act to protect the tympanic membrane, but it has been shown that the latent period of this reflex is such that it would not have time to act in blast injuries, as the pulse wave reaches its maximum in much too rapid a time interval. Some of the ears tested were only slightly over two hours postmortem, and the longest time after death was 14½ hours. There was no distinct relationship evident between length of time postmortem and the pressure necessary to rupture the eardrum membrane. All subjects had been kept refrigerated until examined.

All except two of the eardrum membranes which were ruptured showed tears in the pars tensa, the two exceptions occurring in the pars flaccida; 15 perforated in the anterior half of the pars tensa and eight in the posterior pars tensa. In the two cases where the perforation could not be found, the pressure registered just prior to a sudden drop in pressure (accompanied by an audible escape of air through the Eustachian tube and nose) was recorded as the breaking pressure. That there is a measurable loss of pressure between the gauge and the eardrum membrane is admitted, but is not considered significant in the gross measurements taken here, nor of clinical value because of the range of pressures in the series.

After arriving at an average figure for the pressure at which a human eardrum might be expected to rupture, what then becomes of more import is the question of practical application of these figures. Vail[49] has already reported that two different patients had ruptured eardrum membranes from positive pressures of 27 and 30 pounds per square inch respectively, and so the necessity of a caisson worker having functional Eustachian tubes (and voluntarily opening them)

FORMULATION.

To Change lbs./in.² to Decibels.

Threshold of hearing = 10^{-10} Microwatts/cm.²

Sound level in decibels 0.

$$\text{Intensity} = \frac{\text{Power}}{\text{area}}$$

$$= \frac{\text{Force} \times \text{distance}}{\text{time}} \Big/ \text{Area.}$$

10^7 dyne-cm. or ergs = 1 joule.

1 joule/sec. = watt.

$$\text{Watts/cm.}^2 = \frac{\text{dyne}}{10^7} \quad \frac{\text{(cm.)}}{\text{(sec.)}} \Big/ \text{cm.}^2$$

10^6 microwatts = 1 watt.

$$\text{Microwatts/cm.}^2 = \frac{\text{dyne}}{10^7} \quad \frac{\text{(cm.)}}{\text{(sec.)}} \times \frac{10^6}{\text{cm.}^2}$$

(cm./sec. = velocity) $\dfrac{\text{dynes}}{10^7} \times \dfrac{\text{velocity} \times 10^6}{\text{cm.}^2}$

Velocity of sound = 33100 cm./sec. at 0° C. and increases 61 cm./sec. for each 1° C. rise above 0° C.

$$\frac{\text{dynes}}{10} \times \left(\frac{33100 + (61 \times t^\circ \text{ C.})}{\text{cm.}^2} \right)$$

$$\text{or } \frac{\text{dynes}}{\text{cm.}^2} \times \left(\frac{33100 + (61 \times t^\circ \text{ C.})}{10} \right)$$

Acceleration of gravity = 980 cm./sec.²

$$\text{dynes/cm.}^2 = \text{lbs./in.}^2 \times \frac{454 \times 980}{2.54 \times 2.54}$$

$$\text{lbs./in.}^2 \times \frac{454 \times 980}{2.54 \times 2.54} \times \frac{33100 + (61 \times t^\circ \text{ C.})}{10}$$

= microwatts/cm.²

$$\text{Decibels} = 10 \log \frac{E}{E^\circ}$$

$E^\circ = 10^{-10}$ microwatts/cm.² = Threshold of hearing.

$$\text{Decibels} = 10 \log \left(\frac{\text{microwatts/cm.}^2}{10^{-10}} \right) = \text{Intensity.}$$

$$10 \log \left(\frac{\frac{\text{lbs.}}{\text{in.}^2} \times \frac{454 \times 980}{2.54 \times 2.54} \times \frac{33100 + 61\ t^\circ \text{ C.}}{10}}{10^{-10}} \right) = \text{Intensity in decibels.}$$

Now in this formula $\dfrac{454 \times 980}{2.54 \times 2.54} = 68{,}980$ or a constant of 69,000 and if the average temperature is assumed to be 30° C., then $\dfrac{33{,}100 + 61 \times 30}{10} = 3{,}493$ or as a constant 3,500 and the formula is reduced to:

$$10 \log \left(\frac{\text{lbs./in.}^2 \times 241{,}000{,}000}{10^{-10}} \right) \text{ or}$$

$$10 \log \quad \text{lbs./in.}^2 \times 241 \times 10^{18} = \text{Intensity in decibels.}$$

is immediately apparent. Similarly, Armstrong and Heim[3] have indicated the practical value of this knowledge in aviation. Numerous articles have indicated the relation of these figures to underwater diving, as in a recent review by Martins.[36] Another phase is the relation of these pressure-rupture figures to sound. Perlman[40] states (probably indirectly quoting Collier[9]) that if a 200-pound bomb exploded in State Street, Chicago, everyone on the street within a radius of 50 feet from the bomb would likely have ruptured eardrums.

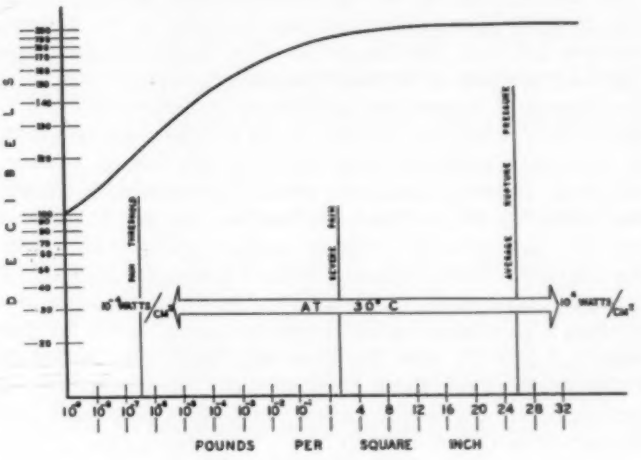

Chart 2.

As the atom and hydrogen bombs and jet engines have opened new vistas in sound study, and a recent judicial verdict has made hearing loss due to acoustic trauma in industry compensable, it would seem well to know at what decibel intensity a human eardrum membrane might be expected to rupture. It then becomes necessary to convert decibel intensity to pounds per square inch. The earliest successful attempts to measure sound velocity in air were those of Marin Mersenne, a French physicist in 1640, and two Italian physicists, Borelli and Vivani, in 1656. One of the most recent, detailed and apparently accurate measurements of sound

velocity was done by Miller[37] in 1934. The conversion of decibels (microwatts/cm.^{2}) to lbs./in.^{2} is dependent upon two values being constant, namely velocity and temperature. This is because the velocity of sound varies directly with the temperature and the variant between watts/cm.^{2} and lbs./in.^{2} is (flow) cm./sec. (velocity); therefore, in any description of lbs./in.^{2} in terms of decibels (watts/cm.^{2}), it is necessary to state at what temperature the conversion is made, as this in turn would alter the velocity (see Formulation).

By substituting in the above formula it would seem that a human eardrum membrane may be expected to rupture at between 195 and 199 dbs. at 30° C. The threshold of pain, 120 dbs., is equal to .0000005 pounds per square inch, and if the figures of Armstrong and Heim are accepted, then very severe pain occurs at 186 dbs. if the temperature be taken at 30° C. (see Chart 2). It is felt that the system utilized in this study approximates that present in conditions resulting in *low frequency*, sonic, traumatic perforations and consequently may be expected to give higher decibel figures than would be encountered if high frequency sound waves were utilized. For example, Davis et al.[15] in 1949 described a perforation of the tympanic membrane after exposure to a 6500 frequency sound at 156-164 dbs. for five minutes. The low decibel figure attained by these workers may be due to the high frequency of the sound wave (and duration) and lower temperatures (not recorded).

SUMMARY AND CONCLUSIONS.

1. The literature concerning tympanic membrane rupture due to air pressure has been reviewed.

2. Tympanic membranes of recently deceased human beings have been ruptured by the application of air pressure by way of the external auditory canal, and the myringorupture pressures recorded.

3. The tympanic membrane reacts differently to sound pressures from high and low frequency waves, and this study probably more closely resembles results to be found in low frequency sound trauma.

4. Some clinical correlations are suggested as related to decibel intensity, air pressure and myringorupture.

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LARYNGOLOGIC EXPERIENCE IN BULBAR POLIOMYELITIS.*

CHARLES P. LEBO, M.D.,†

San Francisco, Calif.

"When you know a thing, to hold that you know it; and when you do not know a thing, to allow that you do not know it: this is knowledge." CONFUCIUS, Analects, Book II, Chap. XVII.

A critical evaluation of the experiences of a consulting laryngologist on the poliomyelitis service of an active, private communicable disease hospital is presented. This report may appear to be redundant and ill-timed, since it is written in the wake of a large number of excellent articles on the recognition and management of the respiratory complications of poliomyelitis, published by competent observers, and is offered at a time when the incidence of this dreaded neurotropic virus disease is declining.

Why then, does the author have the temerity to undertake the writing of still another paper on this subject? The answer lies in the writer's strong conviction that there remains much to be learned about the prevention, diagnosis, and treatment of the respiratory complications of poliomyelitis. At the beginning of his clinical contact with the disease, the essayist prepared himself by means of an extensive review of the pertinent literature and discussion of the subject with physicians qualified by actual clinical experience with poliomyelitis. Initially, all phases of the laryngologic management of bulbar poliomyelitis seemed to be very clear to the author; however, as his experience with the disease became greater, he began to perceive that the indications for laryngologic intervention in bulbar poliomyelitis in a disturbingly large number of cases, were not clearly delineated. After several

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†From the Communicable Diseases Service of Children's Hospital, San Francisco, Calif., and the Division of Otorhinolaryngology, Department of Surgery, Stanford University School of Medicine.

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years of clinical experience with the disease, the author found himself distressed by his progressive inability to give categorical answers to questions posed by members of the house staff, questions which he had previously thought to be easily answerable. The writer was thus stimulated to take inventory of his knowledge and ignorance with the aid of a review of the case records of patients in this category admitted to Children's Hospital during the years 1948 through 1956.

OBJECTIVES.

The objectives of this study are:

1. To review the literature concerning the role of the otolaryngologist in the management of bulbar poliomyelitis.

2. To study the cases encountered by the author and his colleagues at Children's Hospital and to compare their experiences with those of other groups reporting from similar institutions.

3. To describe the *modus operandi* of the poliomyelitis team at Children's Hospital.

4. To formulate certain general principles which might serve to guide other otolaryngologists in the therapy of the respiratory complications of bulbar poliomyelitis, and those of other diseases in which analogous problems occur.

BACKGROUND.

Much has been written during recent years of the respiratory complications of poliomyelitis, and particularly those of the bulbar form of the disease. In 1929, Durand[1] published what appears to be the first report concerning the dangers of the hypopharyngeal secretions to the patient with bulbar poliomyelitis. He described two cases in which postural drainage appeared to be beneficial. Shaw,* in his discussion of this paper, made the following remarks, which may serve well as the theme of this discourse: "... the tendency of these cases is to progress rapidly to death or to complete recovery..." and "...successful employment of Dr. Durand's

*Shaw, E. B., Chief of the Communicable Diseases Service, Children's Hospital, San Francisco, Calif.

method simply removes a great obstacle in the way of complete recovery."

Wilson,[2] in 1931 observed that poliomyelitis may interfere with respiration in three ways: *1.* directly, by actual paralysis of the intercostals and diaphragm; *2.* directly, by involvement of the respiratory centers in the medulla; *3.* indirectly, in patients with pharyngeal paralysis, by secretional obstruction with or without associated glottic spasm. He stressed the importance of differential diagnosis of the nature of the respiratory difficulty as a basis for rational management. He did not mention tracheotomy.

In a review article published in 1936 Davison,[3] in reference to the care of patients afflicted with bulbar poliomyelitis, recommended that the foot of the bed be elevated for postural drainage, and that the hypopharyngeal secretions be aspirated frequently. Gastric tube feedings, intravenous infusions, and proctoclysis were advocated as methods of choice in providing nourishment for these patients. Finally this author stated that in such cases the use of the respirator is contraindicated, but that tracheotomy may be indicated.

Wilson,[4] commenting in 1941 upon the use of the respirator emphasized that patients having respiratory difficulty, due to bulbar paralysis, are not helped by this device, but are actually made worse by its use. He reaffirmed the importance of careful examination and evaluation of poliomyelitis patients with emphasis upon the differential diagnosis of respiratory difficulty. Recommended therapy included postural drainage, aspirations of the pharynx, and even tracheotomy, although no actual experience with the latter procedure is mentioned.

The first report of actual tracheotomies in bulbar poliomyelitis (encountered by the essayist in his review of the literature) was that of Galloway,[5] who is 1943 described the use of tracheotomy in two cases, with subsequent recovery in both patients. This report also describes a third case in which the patient died during preparation for tracheotomy. Two years later, Nelson-Jones and Hunt Williams[6] reported one case of bulbar poliomyelitis, occurring in a British dental

officer, with survival after a tracheotomy. In 1947, Hamilton[7] asserted that the indications for tracheotomy are not clear cut, and possibly they may never be.

In their account of 400 cases of bulbar poliomyelitis treated in the Minneapolis epidemic of 1946, Priest, Boies, and Goltz[8] reported 75 tracheotomies. Of the operated patients, 29 recovered. The mortality in the non-tracheotomized group of patients is not included in their report. Galloway and Seifert[9] reported in 1949 concerning 14 patients afflicted with bulbar poliomyelitis, all of whom recovered following tracheotomy. In this classic paper the problem of respiratory complications in poliomyelitis is presented in a concise, yet comprehensive manner. Using drawings of a model, the authors demonstrate the physical basis for the effectiveness of tracheotomy as a by-pass for preventing aspiration of pharyngeal secretions in patients with bulbar paralysis. They stress the need for this tracheotomic by-pass when patients, having pooling of secretions due to pharyngeal paralysis, are placed in respirators. According to these authors, the respirator is not only not contraindicated for patients with bulbar involvement, but that this device is actually helpful to such patients providing they are afforded the protection of tracheotomy. Galloway and Seifert offer the following indications for tracheotomy in bulbar poliomyelitis:

1. Progressive anoxia with secretions in the upper airway.

2. Unconsciousness or pronounced restlessness in a patient who does not respond to other treatment in a few minutes.

3. Pronounced restlessness or stupor in a patient in a respirator, even if the paralysis is apparently of a spinal type.

4. Food accumulation, not otherwise certainly taken care of, in a patient who requires a respirator.

5. Bilateral paralysis or spasm of the vocal cords.

6. Rapidly progressive bulbar symptoms.

7. Grave signs of vasomotor failure.

8. Untrained or inefficient attendants, inadequate equip-

ment, or poor cooperation of the patient, with doubt that the airway will be kept constantly free of secretions.

West and Bauer,[11] also reporting in 1949, gave a different set of indications for tracheotomy:

1. Definite bulbar signs such as nasal voice, signs of interference with swallowing, and pooling which endangers the airway.

2. Bulbar or spinal cases, at first doing well, but later showing gradually increasing anoxia, whether in or out of the respirator.

3. Atelectasis.

4. Vocal cord paralysis.

Lenarsky,[12] reporting in 1950 from the Willard Parker Hospital in New York, questioned the value of tracheotomy in bulbar poliomyelitis, and presented a mortality of 72.7 per cent in tracheotomized cases as opposed to a mortality of 24.4 per cent in non-tracheotomized cases. This author advocated that bulbar poliomyelitis patients be treated, not by a single physician, but by a team of specialists, including the internist or pediatrician, the otolaryngologist, the orthopedist, the physiatrist, and the psychiatrist. Lenarsky emphasized that the otolaryngologist should not be sought for the tracheotomy alone, but should function as a part of the team in the early treatment of the patient.

Stimson,[14] in 1950, presented still another set of indications for tracheotomy. These were:

1. Bilateral abductor paralysis of the vocal cords. This causes a mechanical obstruction which must be by-passed.

2. Inability to keep the airway reasonably clear. Some clinics with good teamwork can be notably more successful in this than others that are overcrowded or have inadequate or untrained personnel.

3. Progressive hypoxia, not otherwise correctible.

The same author enumerates the following as disadvantages of tracheotomy:

1. The operation is at best an ordeal to the patient, who needs rest and a minimum of handling.

2. There are possible complications.

3. The mortality following tracheotomy in polio is high.

4. The tracheotomy tube narrows the airway and, as a foreign body, it increases endotracheal secretions.

5. Tracheotomy makes oxygen administration difficult unless a proper oxygen attachment is available.

Since these earlier reports, a multitude of other papers have been published on the subject of tracheotomy in bulbar poliomyelitis. Almost without exception, these accounts have echoed the reasoning of Galloway, and have confirmed his results.

REPORT OF CASES.

During the years 1948 to 1956 inclusive, the total number of poliomyelitis cases admitted to Children's Hospital was 2,158. Of these cases, 345 were of the bulbar and bulbospinal types; the overall mortality in this group was 19.4 per cent, or 67 deaths. Tracheotomies were performed in 40 cases having bulbar involvement. There were 15 deaths (37.5 per cent) in the tracheotomized group. Endotracheal intubation, planned as a temporary measure, was performed in six moribund, comatose, respirator cases, all of which expired.

Fig. 1 shows, year by year, the total number of patients with bulbar involvement, their mortality, and the number of tracheotomies performed. This table demonstrates graphically that, in our series of cases, no apparent relationship exists between the total number of cases, the number of tracheotomies performed, and the mortality statistics. As an example of this lack of correlation, let us compare the years 1951 and 1952. In the year 1951, 67 cases of bulbar and bulbospinal poliomyelitis were admitted to Children's Hospital; in this series of cases two tracheotomies were performed and the overall mortality was 12 cases or 17.8 per cent. In the year 1952, of a total of 59 cases with bulbar involvement, there

were ten tracheotomies, nine deaths, and an overall mortality of 15.2 per cent. Certainly the case data from 1951 and 1952, as well as those of the other years included in this study, do not enable one to conclude that the mortality experience in bulbar and bulbospinal poliomyelitis cases at Children's Hospital was significantly influenced by the number of treacheotomies performed.

Fig. 2 indicates that in our series of patients, the mortality in the bulbar cases was approximately twice that occurring

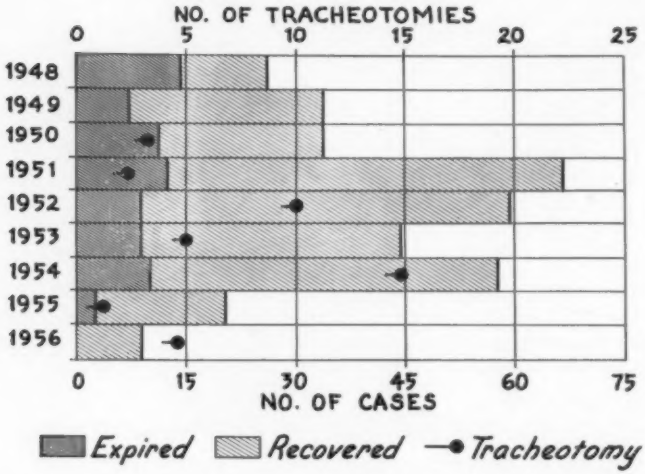

Fig. 1. A graph showing the total number of bulbar and bulbospinal poliomyelitis cases year by year, together with data concerning the mortality experience and the number of tracheotomies performed.

in the bulbospinal cases. Shaw[19] explains this finding on the basis that patients with bulbospinal poliomyelitis tend to have mild, widely-disseminated central nervous system involvement, while patients with pure bulbar poliomyelitis are more likely to have more severe local involvement occurring in vital centers.

A comparison of our experience with that of four other groups is illustrated in Fig. 3. In the percentage of bulbar

Type	Total Cases	Mortality
Bulbar	115	33 or 28.7%
Bulbospinal	230	34 or 14.8%

Fig. 2. The comparative mortality experience at Children's Hospital in bulbar polio myelitis and in bulbospinal poliomyelitis during the years 1948 to 1956, inclusive.

Reporting Group or Institution	Total No. Bulbar Cases	Tracheotomy Cases	Deaths in Tracheotomy Cases	Deaths in Non-Tracheotomy Cases
Minneapolis Gr., 1946	400	75 (18.7%)	46 (61.3%)	not specified
Evanston Hospital, 1947-50	63	25 (39.6%)	—— 10 ——	
Los Angeles County Hospital				
a. 1946	129	14 (10.8%)	7 (50%)	31 (26.9%)
b. 1948	600	230 (38.3%)	—— 123 ——	
Willard Parker Hospital, N. Y., 1948-1949	171	11 (6.4%)	8 (72.7%)	39 (24.4%)
Children's Hospital, San Francisco, 1948-1957	345	40 (11.6%)	15 (37.5%)	52 (17.0%)
Combined Experience (based upon specified data in each category)	1708	395 (23.1%)	76 (54.3%)	122 (18.9%)

Fig. 3. This chart is a comparative compilation of the experience of the designated groups or institutions with tracheotomy in bulbar poliomyelitis. The percentages expressed are based only on those reports which included a complete breakdown of data within the terms of reference of this chart.

cases tracheotomized, Children's Hospital occupies a median position. Our death rate in both the tracheotomized patients and in the non-tracheotomized patients is the lowest of all groups in whose reports these statistics are specified. Like the investigators at Los Angeles County Hospital and at Willard Parker Hospital, we found the mortality to be higher in the tracheotomized bulbar cases than in the non-tracheotomized bulbar cases.

LARYNGOLOGIC MANAGEMENT OF POLIOMYELITIS CASES AT CHILDREN'S HOSPITAL.

The facilities at this institution are particularly favorable for the care of poliomyelitis patients. The communicable

disease building is well equipped, and is generously staffed with resident physicians, interns and experienced nursing personnel. During the period covered by this report a group of consulting laryngologists participated on a "poliomyelitis team" which, in addition to the attending physicians and the house staff, included anesthesiologists. The laryngologists were consulted as early as possible, thereby giving them the opportunity of following each case with manifest or developing bulbar involvement, and thus enabling them to gain a dynamic perspective of each individual problem. Because of the care it was possible to render under these circumstances, the indications for tracheotomy at Children's Hospital differed from those reported by physicians working in similar institutions.

TRACHEOTOMY.

The indications for tracheotomy at Children's Hospital are best presented in reference to those of Galloway, which are widely accepted as the standard indications for this surgical procedure in poliomyelitis. Galloway's first indication (progressive anoxia with secretions in the upper airway), his fifth indication (bilateral paralysis or spasm of the vocal cords), and his sixth indication (rapidly progressive bulbar symptoms) are considered to be quite important by the author and his colleagues.

We differ from Dr. Galloway in reference to his second (unconsciousness or pronounced restlessness in a patient who does not respond to other treatment in a few minutes), and third (pronounced restlessness or stupor in a patient in a respirator, even if the paralysis is apparently of a spinal type) indications. It is our opinion that it is imperative in such situations to determine the etiology of the restlessness or of the comatose state before instituting therapeutic measures; tracheotomy, under the conditions specified in these two indications, may often be inappropriate therapy.

Indication four (food accumulation not otherwise certainly taken care of in the patient who requires a respirator) is not generally applied, since the use of intravenous and tube feedings eliminates this problem; however, such patients

require extremely close observation and may have need for tracheotomy for other reasons.

While indication seven (grave signs of vasomotor failure) may be the result of prolonged hypoxia, such findings may also be due to medullary involvement by the disease process *per se*; hence we do not, as a rule, perform tracheotomies merely on the basis of vasomotor failure.

As some of the foregoing remarks have implied, indication eight, which concerns problems relative to personnel and equipment, is one that we have not had to apply at Children's Hospital. On the contrary, it is believed that many of the bulbar poliomyelitis cases which were treated successfully at this institution without tracheotomy would have been tracheotomized at most other hospitals.

In reference to the indication concerning bilateral vocal cord paralysis, the poliomyelitis team at Children's Hospital considers the presence of unilateral vocal cord paralysis, or paresis, to be a valid indication for tracheotomy, all other factors being considered. Another indication referred to by Galloway, but not included in his list, concerns the patient with mild bulbar involvement, in whom progressive respiratory paralysis necessitates his transfer to a respirator. It has been our policy to protect such patients with preliminary tracheotomies.

Although the indications of Galloway, with the aforementioned modifications, are generally employed at Children's Hospital, the author and his colleagues prefer not to adhere to any specific set of indications. In all patients, the indications for tracheotomy are considered in the light of many important factors, such as the general condition of the patient, the stage and severity of the disease, the presence of pulmonary complications, and the level of consciousness. We consider the situation to be far too complicated to permit the use of any categorical list of indications; nonetheless, we recognize the value of such a list of indications in hospitals in which bulbar poliomyelitis is not frequently encountered.

The main considerations in regard to the indications for tracheotomy in this disease revolve around a careful initial

examination of the patient, which must include either indirect or direct laryngoscopy. When the findings of the initial examination do not indicate tracheotomy, the laryngologist is then obligated to follow the patient with as many subsequent examinations as may be needed for careful evaluation of the patient's progress. We have employed the policy of utilizing postural drainage, pharyngeal aspiration, and other conservative measures in order to evaluate and manage all bulbar patients who were not obvious candidates for immediate tracheotomy.

The following case reports are presented as illustrations of typical situations in which we have not performed this surgical procedure:

Case 1. H. N., a 37-year-old male physician, was admitted on Sept. 17, 1952, with a history of sore throat and fever for five days, gagging and vomiting for two days, and inability to swallow for six hours. Initial examination disclosed a well-developed and nourished, apprehensive person with rhinolalia, hoarseness and gurgling speech. The patient was neither able to cough nor to swallow his secretion. The positive physical findings included marked weakness of the soft palate with deviation of the uvula to the left, pronounced weakness of the pharyngeal constrictors, greater on the right, and a mild but definite adductor paresis of the right vocal cord. The intercostal muscles and the diaphragm were judged to function normally. No weakness nor spasm was demonstrable in the extremities. The lungs were clear.

The patient was given a diagnosis of acute bulbar poliomyelitis and was treated by means of postural drainage, intermittent suctioning of the pharyngeal secretions, and feeding via nasal tube. It was the decision of the staff that this patient, having weathered the storm, would probably continue to improve under conservative management. Tracheotomy was deferred.

The fever, which was 39° C. rectally on admission, lysed rapidly. The patient was afebrile by Sept. 19, 1952. On Oct. 8, 1952, the feeding tube was removed, and the patient was discharged four days later.

COMMENT.

This case report has been included in order to illustrate a statement made earlier in this paper to the effect that the indications for tracheotomy in bulbar poliomyelitis should be tempered with consideration of the stage of the disease process. Certainly this patient would have done very well with a tracheotomy, yet the staff reasoned that since H. N. appeared to be near the end of the acute phase of his disease and had reached this point without the development of pul-

monary complications, tracheotomy might be avoided so long as the clinical picture continued to improve.

Case 2. V. M., a five-year-old boy, was admitted on Aug. 29, 1954, with a history of vomiting and fever of two days' duration, and of headache and backache for one day prior to admission. The initial physical examination revealed slight neck stiffness, partial left-sided facial paralysis, weakness of the pharyngeal constrictors associated with a moderate degree of pooling, and a rectal temperature of 40° C. The sensorium was clear. No cyanosis was observed. The function of the respiratory muscles was unimpaired.

At a conference held on the date of admission it was predicted that since this child was in an early phase of his disease, progression was likely to occur. Accordingly, the boy was given postural drainage, intermittent pharyngeal aspirations, tube feeding, and close observation. On Aug. 30, 1954, progression was evidenced by beginning intercostal paralysis, increased rightsided facial weakness and slight lethargy without cyanosis. It was then decided that immediate tracheotomy should be performed.

The operation was completed without incident under general anesthesia, a No. 2 snorkel tracheotomy tube being inserted.[21] Postoperatively, the child was placed in an open-topped tent which was ventilated with oxygen containing a nebulized detergent.* Forty-eight hours postoperatively, because of increasing respiratory paralysis, with attendant diminution of his tidal volume, the patient was placed in a tank-type respirator. His initial adjustment to the machine was good, and progressive improvement began. The patient was removed from the respirator after five days and was extubated two days later. He was discharged from Children's Hospital on Sept. 20, 1954.

COMMENT.

The case of V. M. is presented for contrast with Case No. 1. The boy was very ill, and still in an early stage of his disease, when admitted. It was anticipated that progression would occur, and unfortunately this prognosis was valid. It became necessary to perform a tracheotomy and eventually, to place the child in a respirator. In retrospect, it would not have been improper to perform the tracheotomy on the day of admission. This case serves to reinforce the thesis that the indications for tracheotomy in bulbar poliomyelitis should be tempered by the chronology of the disease process.

Case 3. Mrs. S. M., a 41year-old housewife, was admitted to Children's Hospital on Aug. 4, 1951, twenty-four hours after the sudden onset of headache, fever, and inability to swallow. On admission, the patient was quite restless and presented a complete paralysis of the left facial nerve, deviation of the tongue to the right, pooling of secretions in the hypopharynx, fixation of both vocal cords in abduction, and the characteristic signs of meningeal irritation. Although she was dusky in color initially,

*Alevaire, Winthrop Laboratories, New York.

her color improved promptly with elevation of the foot of her bed, nasal oxygen and intermittent pharyngeal suctioning.

One hour after admission the patient suddenly became cyanotic and appeared to have no respiratory exchange. She was immediately placed in a tank respirator and was provided with an endotracheal airway. Again her color improved, particularly after aspiration of the contents of the tracheobronchial tree through the endotracheal tube. The patient maintained this improvement for 90 minutes, and then expired.

COMMENT.

This woman suffered an overwhelming invasion of her central nervous system by the poliomyelitis virus. In her management, the insertion of an endotracheal tube offered all that might be expected from a tracheotomy, but did not expose her to a surgical procedure at a time when her life was in jeopardy. Had she responded to therapy, a tracheotomy would have been performed before removal of the endotracheal tube.

Endotracheal intubation has a very definite place in the management of bulbar poliomyelitis. Certainly, it is a desirable substitute for an emergency tracheotomy. Another advantage of the procedure is that it may be done at any hospital by the anesthesiologist on duty, should the arrival of the otolaryngologist be delayed.

TECHNICAL CONSIDERATIONS.

It so happened that local and general anesthesia were used with equal frequency in the entire series of cases. Local anesthesia predominated in the earlier years, while general anesthesia predominated in the more recent years. Both types of anesthesia were found to be satisfactory and well tolerated, even in very sick patients.[31] General anesthesia was initially employed to facilitate the care of respirator patients, but as our experience with this technique grew, we elected to use it also in patients whose disease did not necessitate the use of the respirator. Currently at Children's Hospital, general anesthesia is considered the method of choice for respirator cases and is utilized interchangeably with local anesthesia in non-respirator cases.

Whenever possible, patients requiring tracheotomy were

removed to the operating room of the communicable disease building. Respirator patients were usually transferred to an operating table as a preliminary to tracheotomy. Removal of the patients from the respirators was accomplished after induction of general anesthesia, with endotracheal intubation enabling the anesthesiologists to render artificial respiration throughout the procedures. It was thus possible to avoid the pitfalls of performing this operation in the respirator. Arti-

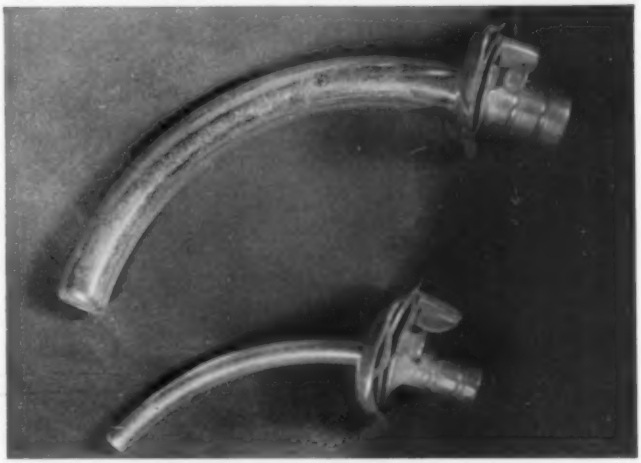

Fig. 4-A. Lateral view of snorkel tracheotomy tubes in sizes No. 5 and No. 0.

ficial respiration after insertion of the tracheotomy tube, and before replacement of the patient in the respirator, was simplified with the use of the snorkel tracheotomy tube.[21] It is pointed out that this special tracheotomy tube has also been helpful in facilitating the respirator care of tracheotomized patients. (The snorkel tracheotomy tube is illustrated in Figs. 4, 5).

BRONCHOSCOPY.

While bronchoscopy as a single or repetitive procedure is

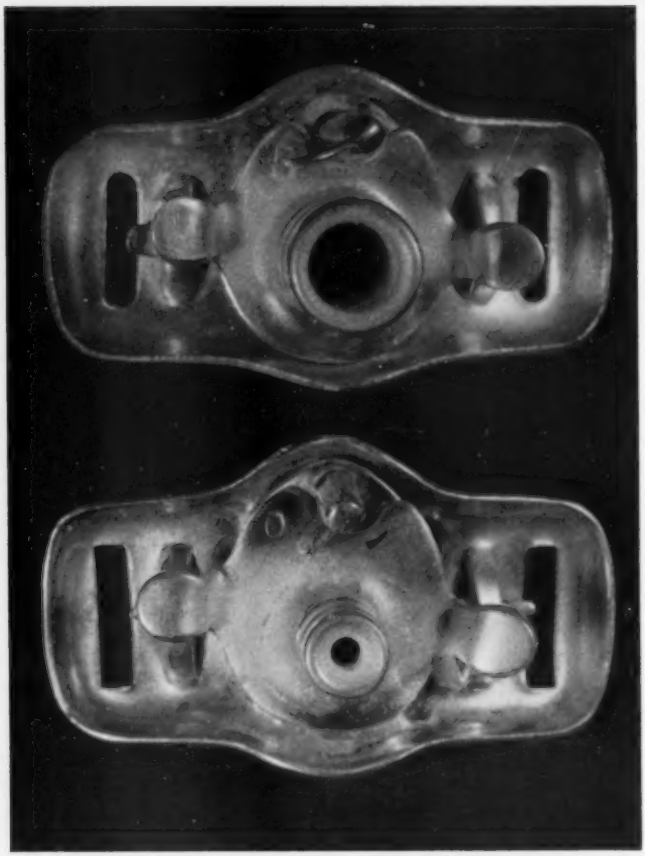

Fig. 4-B. Anterior view of snorkel tracheotomy tubes in sizes No. 5 and No. 0.

often performed independently of tracheotomy in bulbar poliomyelitis, it was frequently undertaken as a preliminary to this surgical procedure. When a bronchoscopy preceded a tracheotomy, the bronchoscope was usually left in the trachea during the surgery. By means of a heavy flow of the anesthetic mixture, artificial respiration was administered very

satisfactorily through bronchoscopes of the type which is fitted with an oxygen adapter near the proximal end.[32]

We have favored general anesthesia for peroral bronchoscopy in nontracheotomized respirator patients because we have seldom obtained satisfactory topical anesthesia in this group of patients. The difficulty in inducing adequate topical anesthesia in this group is attributed to both the pooled secretions in the pharynx and to the recumbent position. Under these circumstances thiopental sodium and a curarizing agent are administered intravenously. The respirator pro-

Fig. 5. Illustration of snorkel tracheotomy tube in use as viewed from outside of respirator. Note the end of the tube emerging from the sponge rubber collar of the respirator; this is an endotracheal tube, the opposite end of which is attached to a snorkel tracheotomy tube inside the respirator.

vides artificial respiration during anesthesia as well as in the preanesthetic and postanesthetic periods. General anesthesia is not required in bronchoscopic procedures performed through tracheotomies. In this instance topical anesthesia is employed, except for comatose patients in whom no anesthesia is required. A major advantage of tracheotomy is that it facilitates bedside bronchoscopy.

POST-TRACHEOTOMY CARE.

As pointed out by Negus,[33] the previously anoxic patient may be in danger after a successful tracheotomy because of apnea induced by a rapid loss of excess carbon dioxide re-

sulting from restoration of an adequate airway at a time when the chemoreceptors are no longer responsive to the normal range of plasma carbon dioxide concentrations. Although no complications of this sort were encountered in our series of cases, we have been aware of this possible danger and have taken the recommended precautions against it.

It is considered advisable to change tracheotomy tubes every 48 hours for the first seven to ten days, and twice weekly thereafter. Although extra large tracheotomy tubes have been advocated by other workers,[34] we have not encountered a need for their use.

The procedure of aspiration of the tracheobronchial tree through the tracheotomy tube is to be undertaken with caution, since pulmonary complications may follow traumatic suctioning. Plumb and Dunning,[35] and Conley,[36] have emphasized these dangers, and both have suggested methods of avoiding such trauma.

EXTUBATION.

It is believed that allowing the tracheotomy tube to remain in place should be considered to be just as active a process as electing to perform the tracheotomy. The tracheotomy tube, which is no longer needed, is both a physical and psychological detriment to the welfare of the patient who wears it. The duties of the laryngologist do not end with the termination of the acute phase of the tracheotomized poliomyelitis patient's illness; he is obligated to follow the progress of the patient and to extubate at the proper time. Successful extubation demands the judicious use of the art of medicine and requires a positive, confident attitude on the part of the laryngologist.

The tracheotomy tube constitutes a foreign body, and as such evokes the formation of excessive secretions. The presence of such secretions does not necessarily indicate that the tube is still needed.

DISCUSSION.

Many reports of tracheotomy in bulbar poliomyelitis list

groups of cases in which tracheotomy is regarded as a life-saving procedure. This author is unable to conclude that tracheotomy was life-saving nor that this procedure was not life-saving in any of the surviving cases included in this report. The clinical picture is far too complicated. Many of our patients exhibited dramatic initial improvement after tracheotomy, but subsequently died; some patients showed no change after tracheotomy, but recovered; other patients maintained whatever improvement followed tracheotomy.

Most authors stress the importance of clinical hypoxia in their lists of tracheotomy indications and include restlessness, anxiety, hyperpnea, flushed fascies, tachycardia, lethargy, coma, and cyanosis as manifestations of hypoxia. In this they are indeed correct; however, most of the features of this clinical picture also occur in viral invasion of the higher centers, in hypokaliemia, and in disturbed acid-base balance; hence the presence of the aforementioned symptoms and physical findings is not specific. Even when hypoxia is demonstrated by oximetry, these other conditions may also be present. It may, therefore, be concluded that tracheotomy is most useful in those cases in which these "hypoxic symptoms" are due primarily to hypoxia resulting from respiratory obstruction in the hypopharynx and in the cephalic portions of the tracheobronchial tree. Tracheotomy may be futile when these "hypoxic symptoms" are principally the result of conditions other than hypoxia.

The differential diagnosis of the etiology of "hypoxic symptoms" is most difficult, even with the assistance of laboratory tests, which time may not always permit. This differential diagnostic problem, however, should not deter one from performing a tracheotomy if the procedure appears to be indicated. The coexistence of extensive spread of the virus in the medulla, altered electrolyte metabolism, and impaired acid-base equilibrium with primary and secondary hypoxia accounts for a large proportion of the deaths occurring in tracheotomized (as well as non-tracheotomized) bulbar and bulbospinal poliomyelitis patients.

It is considered significant that no complications attribut-

able to tracheotomy were encountered in any of the patients in this series; furthermore, evaluation of the records (including autopsy reports) of patients expiring after tracheotomy in no case indicated that tracheotomy was a factor contributing to the patient's demise. Stimson[14] states that the mortality following tracheotomy in poliomyelitis is high; it is conceded that Stimson is correct in this contention. *The reason for the high death rate in tracheotomized poliomyelitis patients is that this operation is usually performed on patients afflicted with the severest forms of this disease, and in whom the anticipated mortality is very high.* It is believed that the mortality scores for tracheotomized poliomyelitis patients would, in all series, be significantly higher if these patients had not been afforded the benefits of tracheotomy.

The task of evaluating therapeutic procedures in poliomyelitis is most difficult. Since this disease exhibits marked annual and geographic variations in incidence and severity, controlled studies are not feasible. As is illustrated in Fig. 1, there is no constant relationship in our series of cases between the incidence of bulbar poliomyelitis cases, their mortality, and the number of tracheotomies performed. This observation serves to point out the fallacy of attaching too much significance to reports of the results of tracheotomy in poliomyelitis which include but one year, or even a few years, of experience.

SUMMARY.

A comparison of nine years of experience at Children's Hospital with 345 cases of bulbar poliomyelitis, with similar experience reported by four other groups demonstrated that:

1. Children's Hospital occupied a median position in regard to the percentage of such cases in which tracheotomy was performed.

2. The mortality experience at Children's Hospital in both tracheotomized and in non-tracheotomized bulbar poliomyelitis cases is the lowest of that of all groups specifying these statistics.

No definite conclusions are drawn from the case data included in this report. All that may be said is that the experience of the staff of Children's Hospital did not differ significantly from the experience reported by others working with this disease.

CONCLUSIONS.

1. The indications for tracheotomy in bulbar and in bulbospinal poliomyelitis are ill-defined. Therapy based upon the standard indications may often be inappropriate. Each case must receive consideration as an individual problem.

2. Tracheotomy is most beneficial when done early, *i.e.*, before the occurrence of pulmonary complications and hypoxic central nervous system damage, both of which the operation is intended to prevent.

3. General anesthesia, in our experience, is a safe and satisfactory technique for use in bulbar poliomyelitis. It permits removal of the respirator patient from the respirator, and thus avoids surgical complications due to inadequate exposure.

4. Bronchoscopy is a valuable adjunct in the management of bulbar and bulbospinal poliomyelitis, and may be employed for the prevention, as well as the treatment of, pulmonary complications.

5. The necessity for meticulous evaluation of the bulbar poliomyelitis patient by the team of consultants, both initially, and at each stage of the disease, cannot be overemphasized.

6. The use of endotracheal intubation, both in lieu of emergency tracheotomy and as a means of providing a temporary airway for very ill patients, is recommended.

7. Whenever in the management of bulbar poliomyelitis patients the need for tracheotomy cannot be ruled out, the operation should be performed.

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UNIVERSITY OF MICHIGAN MEDICAL CENTER.

The annual Otolaryngology Conference at the University of Michigan will be held April 16, 17 and 18, 1959, under the direction of Dr. James H. Maxwell, Chairman of the Department of Otolaryngology.

Applications may be addressed to the Department of Postgraduate Medicine, University Hospital, Ann Arbor, Mich.

STUDIES OF FACTORS CONSIDERED RESPONSIBLE FOR DISEASES OF THE EXTERNAL EAR.*†

I. Survival of Exogenous Bacteria in the External Auditory Canal Under Varied Conditions.

BEN H. SENTURIA, M.D.,
and
CHARLES D. CARR, M.T.,
St. Louis, Mo.

INTRODUCTION.

The factors suspected of contributing to diseases of the external auditory canal are numerous. Some investigators believe that prolonged exposure to high temperatures and high relative humidities is of prime importance in the production of external otitis. On the other hand, it has been proposed that low relative humidities and low temperatures, leading to desiccation of the skin, constitute a means by which the natural defense mechanism of the skin is overcome. Others are of the opinion that removal of surface lipids and/or trauma break the natural barrier against infection and may, at the same time, provide the means by which exogenous microorganisms are implanted on the surface of the skin.

In this study, attention has been directed towards some of these factors, *viz.*, temperature, humidity, trauma and the removal of the surface lipids, as they influence the survival of exogenous organisms in the external auditory canal of the cat.

LITERATURE REVIEW.

Reports of external otitis occurring in hot, humid environ-

*From the Washington University School of Medicine, Department of Otolaryngology, St. Louis, Mo.

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ments have given support to the hypothesis that elevated temperatures and humidities, and contamination with gram-negative bacilli, play an important role in production of some diseases of the external auditory canal. Much has been written regarding the role of infection in the pathogenesis of diseases of the external ear, and recently this subject was thoroughly reviewed.[1]

During the Second World War numerous cases of external otitis occurred among troops stationed in tropical and subtropical latitudes, and it was thought that elevated temperatures and humidities were factors in the development of the dermatoses.[2-8]

Horne[9,10] showed a relationship between the incidence of such diseases as miliaria and the minimum dry bulb temperature and humidity in India. Senturia[11] and Branca[12] correlated high temperatures and humidities with the incidence of external otitis in certain regions of the United States. On the basis of clinical laboratory observations, the former postulated that prolonged exposure to these environments permitted the absorption of moisture by the stratum corneum, interruption of normal keratinization, plugging of the apopilosebaceous units and, therefore, interference with the delivery of the antimicrobial substances to the surface of the skin of the ear canal.[13]

There are also other indications that the absorption of moisture by the stratum corneum in a hot, humid environment may be related in some manner to the high incidence of external otitis. Mali[14] noted that the permeability of the skin rose with an elevation of environmental relative humidity. Buettner[15] was of the opinion that water and water vapor pass into nonsweating skin in proportion to the surrounding air vapor pressure. Mole[16] and Blank[17,18] demonstrated that the stratum corneum will take up moisture from a high humidity environment. Blank[17] clearly showed that cornified epithelium absorbs increasing amounts of moisture as the relative humidity rises.

Gaul and Underwood[19] suggested that a reduced amount of moisture in the air will influence the pliability, softness and

smoothness of the skin. Blank[20] proposed that a loss in the flexibility and fissuring of the stratum corneum occur when there is a reduction in the moisture content of the skin under conditions of low relative humidity.

Swimming under water and diving can bring about the production of skin maceration and secondary infection of the external ear canal. Failure to remove all the water present in the meatus after swimming was considered the cause of external otitis by Gordon.[21] Punt[22] noted that most of the cases of ear diseases occurred not only during hot, humid weather but also after patients had been swimming.

On the other hand, numerous patients deny any history of swimming prior to symptoms of external ear inflammations.[1] In a series of experiments, Collins[23] produced maceration and desquamation but no secondary infection after filling the osseous portion of the ear canal with chlorinated swimming pool water or sea water. Collins concluded that this factor alone was not enough to cause external otitis. Senturia, however, reported the development of acute external otitis following irrigation of the ear canal with hypertonic saline for the routine removal of ear wax in 13 normal ears.[1]

A factor often implicated in the production of external otitis is trauma produced by the insertion of foreign objects into the ear canal.[4,24,25] In a study by Syverton et al.,[26] it was recorded that 50 per cent of the patients habitually picked at the ear canal. Infection associated with the traumatic removal of foreign objects from the meatus has been described frequently.[1,27]

In observing the effects of trauma and increased humidity on the skin of the meatus, Shelley and Perry[28] obstructed the external ears of adult males by inserting ear plugs and/or applying small strips of adhesive tape to the canal wall. One-half of the subjects showed no changes, while the other half showed a "soggy maceration" of the skin of the canal, which the investigators believed resembled "hot weather ear."

Senturia, experimenting with mice and rabbits at the School of Aviation Medicine,[29] was unable to produce gross lesions of the ear canal by the introduction of pseudomonas

organisms or fungi onto the untraumatized skin but demonstrated extensive morphologic changes following contamination and the application of various irritating acids. Salvin[30] introduced a suspension of *Pseudomonas acruginosa* after excoriating the ears of rabbits, and produced vesicles and papules. Fluid from the vesicles was removed, and "in all cases, pure cultures of the isolate originally inoculated into the ears were obtained." Haley[31] showed that trauma to the skin of the ear canal was a necessary factor in the experimental production of mycotic infections in the rabbit. More recently, Senturia and Liebmann,[32] using cats, demonstrated that contamination or trauma alone did not produce external otitis, but after trauma and contamination with pseudomonas organisms, morphologic and pathologic changes were consistently produced.

Perry and Nichols[33] "liberally seeded" *Pseudomonas aeruginosa* into the untraumatized external auditory canals of human volunteers. One week later the organism could not be recovered, and no clinical evidence of external otitis could be found. Senturia[1] described eight healthy ears with normal bacterial flora in which acute diffuse external otitis developed seven to 17 days after irrigation for removal of ear wax. Positive cultures for *Pseudomonas aeruginosa* were obtained in all cases.

The absence of lipids on the surface of the skin is believed to be a factor in the occurrence of diseases of the external ear.[1] The bactericidal and fungistatic action of the skin lipids may be an important factor in the inhibition of microbic growth as suggested by Ricketts et al.,[34] Burtenshaw[35] and Peck et al.[36]

It has been postulated that high environmental temperature and relative humidity decrease the viscosity of the sebum layer, causing the lipids to spread thinly over a much greater surface area and preventing the formation of an adequate protective coating.[37-39] Gessert et al.[40] were unable to demonstrate any decrease in the lipid covering of the cat and rabbit ear canals after the animals had been exposed to high temperatures and humidities (see Part II).

It is generally accepted that contamination with Gram-negative bacilli plays an important role in the production of diseases of the external ear. Schiemann and Landau[41] showed that a bacterial suspension, especially Gram-negative bacilli, placed on the normal skin of the hand were rapidly destroyed, and they believed that this destruction was due to some mechanical or chemical action. Arnold et al.[42] stated that *E. coli* and *S. typhosa* would remain viable on dirty or fatty skin for short periods. Singer and Arnold[43] showed that the skin, after being washed with soap and warm water, was able to destroy from 90 to 95 per cent of the *B. prodigiosus*,* *B. pyocyaneus, S. typhosus, S. paratyphi, S. enteritidis, E. coli, S. aureus* and *S. albus* within 10 minutes after being applied to the skin. When these same microorganisms were applied to dirty or fatty skin they disappeared more slowly.

Montgomery[44] studied the destruction of *B. prodigiosus* on fingers which were submerged in various dilutions of bacteria and air-dried for 15 minutes. It was noted that the higher the dilution, the greater the percentage of bacteria destroyed. In the undiluted suspension only 25 per cent of the bacteria were destroyed, while 90 per cent were eliminated in the 1:200 dilution. In similar experiments performed by Karns and Arnold,[45] using a 1:50 saline dilution of *B. prodigiosus*, 91 per cent of the bacteria were found to be killed in 60 minutes. These authors believe that despite considerable variations in results, the skin showed a 100 per cent disinfecting power for these bacteria.

Norton and Novy[46] and Bryan and Mallmann[47] disagreed with the findings of Arnold and his associates,[41] and attributed the reduction of bacterial counts to desiccation rather than any specific antibacterial action. Arnold and Bart[48] presented data to show that there was no decrease in the rate of disappearance of organisms kept on moist skin, and no increased sterilizing ability of the skin after scrubbing with soap and water and cleansing with alcohol and ether. They reiterated their belief that factors other than desiccation played an important role in the disappearance of the organisms.

In a study of the factors influencing the growth of endo-

*Serratia marcesens.

genous and exogenous skin bacteria, Pillsbury and Rebell[49] found that various bacteria applied to normal and pathologic skin were markedly decreased after desiccation. Cornbleet and Montgomery,[50] using *Staplylococcus aureus* on various parts of the body, found that moist areas were poor in self-sterilization, and that this power was restored when the skin area was exposed to the air and allowed to dry.

Colebrook[51] showed that approximately 29 per cent of *hemolytic Streptococci* placed on the skin remained viable for one hour and 4 per cent for two hours after drying. *E. coli*, Proteus and Klebsiella appeared to be sensitive to skin-sterilization. Burtenshaw[52] performed similar observations to Colebrook's[51] using streptococci on various skin areas, and suggested that slow self-disinfection occurred after the desiccation phenomenon was over. Colebrook and Maxted[53] pointed out that *Streptococcus pyogenes*, not normally present on the skin of the hands, would spontaneously disappear when artificially implanted on it. They stated that the Coli, Proteus and Friedlander bacilli would also disappear in the same manner.

Price[54] noted that implanted *B. subtilis* could not be found on the hands and arms after three hours, while exogenous staphylococcus, *B. coli* and *Pseudomonas aeruginosa* persisted on the hands for many weeks despite scrubbing and application of germicides. He was of the opinion that certain exogenous microorganisms seemed to be able to adapt to the new environment. Prolonged exposure of the skin to these contaminants could result in their becoming endogenous organisms, and once this transition had occurred the skin could not easily be disinfected.

Rebell et al.[55] reported a series of experiments in which *E. coli*, staphylococcus and streptococcus (Group G) were the test organisms in determining the self-sterilizing ability of the skin. Staphylococci were found to be more resistant to autogenous sterilization than *E. coli*. When the skin lipids were removed prior to contamination, it was noted that there was a marked decrease in the ability of the skin to sterilize itself. It was further shown that in test subjects exposed to high temperatures and humidities for a period of eight hours after inoculation of the skin with *E. coli*, the contaminant was

recovered from a majority of subjects one to two weeks later. These observations concurred with an earlier experiment of this same study, in which it was demonstrated that *E. coli*, and staphylococcus, kept moist by spraying, showed a prolongation in survival time. In a later report, Pillsbury and Rebell[49] found *A. aerogenes, Ps. aeruginosa, Pr. vulgaris,* and *E. coli* to be somewhat more resistant to fatty acids of sebum than *M. epidermidis, albus, candidus, flavus* and coagulase-positive micrococci. The *Corynebacteria (xerose* and *tenuis)* were also slightly sensitive to some fatty acids.

METHODS AND TECHNIQUES.

The skin lining the external auditory canal of the cat has been shown to have skin appendages similar to those of the human (*viz.*, apocrine and sebaceous glands) and, therefore, this animal was chosen for use in this study. Only animals which had been through a quarantine period and showed no signs of either systemic or local disease were selected. The animals were housed in separate cages and fed a balanced diet.

Cultures for bacteria and fungi of the external auditory canal were routinely taken on all animals before and after procedures were performed. The swabs were inoculated onto MacConkey, Sabouraud's and blood agar plates.* In the later series of experiments, swabs of the external ear canals were placed immediately into Tryptose broth, incubated for one hour at 37° C., and then 0.1 ml. of the broth was inoculated to solid culture media. The material was spread over the surface, with an "L" shaped wire needle in order to obtain isolated colony growth. The number of bacterial colonies was recorded as follows: 0 = #; 1-25 = ±; 26-50 = +; 51-75 = 2+; 76-100 = 3+; >100 = 4+.

The microrganisms used to contaminate the external auditory canals of the experimental animals were obtained from patients suffering from acute diffuse external otitis, chronic otitis media or mastoiditis. These included the following

*Citrated whole human blood and defibrinated rabbit blood were used in the preparation of blood agar plates.

bacteria: *Pseudomonas aeruginosa,* hemolytic *Micrococcus aureus* and *Beta-type Streptococcus.*

Biochemical reactions for conclusive identification of the Gram-negative bacilli were performed according to the procedures suggested by Edwards and Ewing.[56] Coagulase and mannite fermentation tests were made on all strains of micrococci used as contaminants. Only those micrococci which gave a strongly positive reaction with these tests were utilized.

In those experiments in which dilutions were prepared, the organism was grown in broth, then serial dilutions were made to the required suspensions. After incubations for one hour at 37° C., 0.5 ml. of broth suspension was instilled into the ear canals. A light cotton packing was inserted into the orifice of the canal to prevent periauricular contamination. Plate counts, performed simultaneously on the diluted suspensions, gave an indication of the number of organisms present.*

Removal of the surface lipid film from the skin of the cartilaginous ear canal was accomplished by using two ether-saturated cotton swabs. Trauma was produced by gently stroking the skin of the ear canal with a ringed metal ear curette until erythema developed. Trauma sufficient to cause bleeding was avoided.

Morphological changes in the skin lining the external ear canals consisted of various degrees of erythema (R), exudate (X), crusting (C), edema (E) and dryness (D). The degree of change was noted as from 4-plus (indicating severe involvement) to plus-minus when only slight changes were found.

When anesthesia was considered desirable, pentobarbitol sodium (approx. 12 mg. per pound of body weight) was injected intrathoracically in cats. The majority of animals were completely recovered within four to five hours.

The temperature in the hot room was controlled automatically† and the humidity sustained within the planned range

*10^{-6} = 1040 colonies/ml.
10^{-7} = 388 colonies/ml.
†Two Chromolon electric heaters, thermostatically controlled by Mercoid Switch.

with humidifiers.* The cool room temperature was maintained by use of a window air-conditioner† and the humidity lowered with a standard commercial type dehumidifier.‡

EXPERIMENTAL PROCEDURES AND FINDINGS.

Experiment A.

Since no data could be found in the literature concerning the microbiologic flora of the normal external auditory canal of the cat, a limited study of the bacterial and mycologic flora was performed. This provided some basis for comparison with the bacterial flora of the human ear and a control on the changes occurring after contamination with exogenous bacteria. Cultures of the external auditory canals of 48 cats (96 ears) were taken after the animals had been maintained at ambient temperatures and humidities in the animal quarters.

TABLE I.—EXPERIMENT A.

Bacteriologic Flora of the Normal Cat and Human External Auditory Canals.

Microorganism	Cat (96 ears)	Human[11] (66 ears)
Pseudomonas group	0.0%*	0.0%*
Proteus group	1.0%	0.0%
Coli-Aerogenes group	5.0%	6.1%
Micrococcus albus	79.2%	10.6%
Micrococcus albus, hemolytic	65.6%	80.3%
Micrococcus aureus	5.2%	10.6%
Micrococcus aureus, hemolytic	7.3%	0.0%
Corynebacteria	1.0%	85.5%
Bacillus sp.	5.2%	15.5%
Streptococcus α, β, and γ types	0.0%	4.4%

*Percentage of ears in which microorganism was found.

It is noteworthy that the bacterial flora of the cat is strikingly similar to that of the human external auditory canal (see Table I). The Gram-positive microorganisms are the most common endogenous bacteria on the skin of the normal external auditory canal. Gram-negative bacilli are cultured

*Walton Humidifier, Model W-F.
†Philco Air-Conditioner, ¾ ton unit.
‡Frigidaire Electric Dehumidifier.

in very small numbers. The Pseudomonas group was not found in the normal human or cat meatus.

Experiment B.

This experiment was designed to determine the effect of high temperatures and high relative humidities on the bacterial flora and morphology of the skin of the normal external auditory canal of the cat.

Two groups of cats were selected: one group of eight cats (16 ears) were placed for a period of four days in a room in which the average temperature was 86° F. and the average relative humidity 95 per cent. Another group, consisting of 20 animals (28 ears)* were exposed to the approximate

TABLE II.—EXPERIMENT B.

Effect of High Temperatures and Humidities upon the Bacterial Flora and Morphology of the Cat External Auditory Canal.

Av. T.* = 86° F. Av. R.H.† = 95%.

No. of Cats	No. of Ears	Period of Observation	Bacterial Flora	Morphology
8	16	4 Days	Unchanged	Unchanged‡
20	28	4-17 Days	Unchanged	Unchanged

*T. = Temperature.
†R.H. = Relative Humidity.
‡Some ears may show an increase in the amount of cerumen.

temperatures and humidities of the first group for a period ranging from four to 17 days.

In neither group was there any noteworthy change in the bacterial flora, or in the morphologic characteristics of the skin lining of the ear canal (see Table II).

Experiment C.

Because of the conflicting information in the literature, this study was performed to determine how long a suspension of *Pseudomonas aeruginosa*, introduced into the external ear canal of the cat, would persist and what morphologic skin changes would occur under conditions of high temperatures

*In this group are included the untreated control ears of other experiments performed at these same temperatures and humidities.

and high relative humidities (Av. T. 81° F.; Av. R.H. 92 per cent).

Five-tenths ml. of an undiluted 24-hour broth suspension of Pseudomonas was instilled into the external ear canal. The animals were examined and cultures of the ear canals taken at two or four-day intervals thereafter (with one exception) for 16 days.

It may be seen in Table III that in all ears the Pseudomonas was still cultured on the tenth or twelfth day after contamination. In four of the 11 ears the bacteria could be recovered on the fifteenth or sixteenth day.

While not consistent in degree, there were some morphologic changes recorded at varying intervals in all ears. Marked changes occurred in the skin lining the ear canals in four of the 11 ears. Six of the ears had a dry appearance, erythema was noted in six, crusting was present intermittently in eight, exudate in three and severe edema in one. At the conclusion of the experiment, six of the 11 ears were normal in appearance.

Experiment D.

It has been demonstrated that an undiluted inoculum of Pseudomonas would survive for a period of weeks in the normal, untreated ear of the cat kept in a hot, moist environment. It was considered desirable to determine whether diluted suspension of the organism would persist under similar conditions.

Five-tenths ml. of a 10^{-6} broth dilution of a 24-hour suspension of *Ps. aeruginosa* was instilled into one ear of each of three cats, and 0.5 ml. of a 10^{-7} dilution of the same organism was used to contaminate one ear of another group of five cats. The contra-lateral ears served as controls. The animals were housed in quarters in which the average temperature was 86° F., and the average relative humidity was close to 100 per cent. Cultures were obtained at intervals for 17 days.

It was noted in the first group (10^{-6} dilution) that there was a gradual diminution in the number of colonies grown, although the organisms persisted in all ears through the

TABLE III.—EXPERIMENT C.

Survival of Pseudomonas (Undiluted) and Morphologic Changes Occurring in the External Auditory Canal of the Cat Under Conditions of High Temperatures and Humidities.

AV. T. = 81° F. Av. R.H. = 92%.

		Days Following Contamination.																	
		0		2		4		6		8		10		12		15		16	
Cat	Ear	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.
38	R	N	Ps.	D	4+	D	4+	R 4+ C 4+ X 2+	±			R 2+ C 4+ X 2+	4+			D C 3+	±		
38	L	N	Ps.	R+	+	D	+	R ± C 2+	4+			R ± C +	±			D C 2+	•		
39	R	N	Ps.	N	4+	N	4+	N	+			R ± C +	±			C +	•		
39	L	N	Ps.	N	4+	N	2+	N	3+			N	±			N	•		
40	R	N	Ps.	R+	4+	N	3+	R ± C 2+ X ±	+			R ± C 2+	3+			C 2+	•		
40	L	N	Ps.	N	4+	N	4+	N	2+			N	2+			N	•		
41	R	N	Ps.			R 2+ C 4+ X 4+	4+			R 3+ X 4+	4+			C 2+ X 4+ E 4+	4+			R + C 3+ E 3+	4+
42	L	N	Ps.			N	4+			D	4+			N	±			N	•
43	R	N	Ps.			D R 2+	4+			D	4+			D C +	±			N	•
44	L	N	Ps.			N	4+			D C +	4+			N	4+			N	4+
45	R	N	Ps.			D C 2+	4+			N	2+			D	4+			N	±

R = Erythema. C = Crusting. X = Exudate. E = Edema. N = Normal. D = Dry. • = No growth of Pseudomonas.

12th day and were present in two of the three contaminated ears on the 17th day.*

In all the contaminated ears of the second group (10^{-7} dilution), cultures remained positive on the 8th day while the organism was recovered on the 12th day in only three of the five ears. The Pseudomonas persisted in only one of the five ears on the 17th day. All control ears remained free of contamination (see Table IV).

TABLE IV.—EXPERIMENT D.

Survival of Pseudomonas aeruginosa (Diluted) in the External Auditory Canal of the Cat Under Conditions of High Temperatures and Humidities.

Av. T. = 85.5° F. Av. R.H. = 99.5%.

Dilution	Cat	Days Following Contamination				
		0	4	8	12	17
10^{-6}	46A	Ps.	4+	2+	3+	+
	49	Ps.	4+	4+	2+	*
	50	Ps.	4+	4+	2+	+
10^{-7}	25A	Ps.	+	+	3+	+
	26A	Ps.	4+	4+	*	*
	27A	Ps.	4+	4+	*	*
	28A	Ps.	4+	4+	3+	*
	29A	Ps.	±	4+	4+	*

*No growth of Ps. aeruginosa.

When these two sets of data are compared and contrasted with the findings after the use of undiluted cultures, it is seen that the percentage of contaminated ears remain the same through the 8th day. The ears which received the more dilute suspension of bacteria appear to return to normal a little more rapidly than do those in which undiluted Pseudomonas was instilled (see Graph 1).

Experiment E.

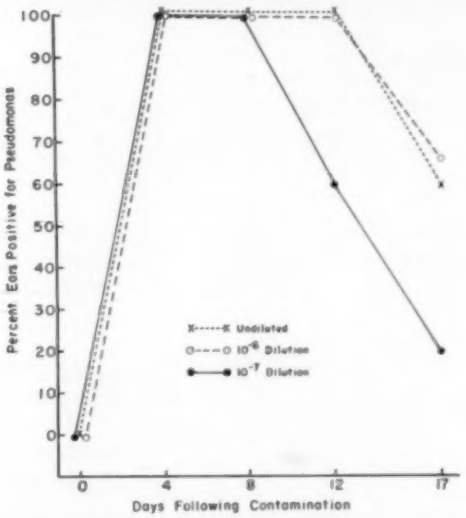
The purpose of this experiment was to determine the length of survival of undiluted cultures of *Micrococcus aureus* and *Beta-type Streptococci* in the healthy meatuses of the cat under conditions of high temperatures and humidities and contrast this with the known survival time of the Pseudomonas organism.

*In one animal, cross-contamination occurred in the control ear.

One ear of each of three cats was contaminated with 0.5 ml. of a 24-hour broth suspension of hemolytic *M. aureus* and two animals with *Beta-type Streptococci.* The contra-lateral ears of three of the animals were contaminated with 0.5 ml. of a 10^{-6} dilution of *Pseudomonas aeruginosa,* and the remaining ears served as untreated controls for the experiment. The

Graph I
Experiment D

Comparison of Percent of Cat Ears Remaining Positive After Contamination with Ps. aeruginosa under Conditions of High Temperatures and Humidities.



animals were placed in an environment of high temperatures and high relative humidities (Av. T. 88° F.; Av. R.H. 96 per cent), and cultures were taken at intervals.

In all three animals contaminated with *M. aureus* there was a heavy growth on the first and second day. There followed a rapid decrease in the number of organisms by the fourth day with all ears being free of the Micrococcus on the sixth,

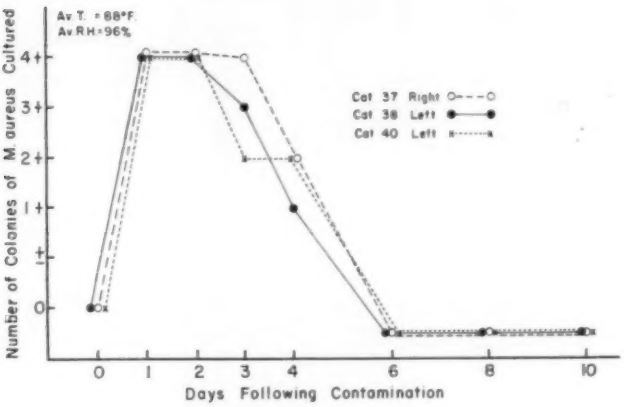
eighth and tenth days (see Graph 2). The streptococci could not be recovered on the first or second day (see Table V). The *Ps. aeruginosa* persisted at a high level in the contralateral ears into which it had been instilled and no cross-contamination occurred.

Experiment F.

In earlier studies it was found that a combination of lipid

Graph 2
Experiment E

Survival of M. aureus (Undiluted) in the External Auditory Canal of the Cat under Conditions of High Temperatures and High Relative Humidities.



removal, trauma, contamination with *Pseudomonas aeruginosa* and exposure to high temperatures and humidities would produce gross morphologic changes of the skin lining of the cat meatus, and that the instilled Pseudomonas would persist over a period of seven to 19 days.[32]

In order to verify these observations, the ears of four cats (seven ears) were subjected to conditions of high temperatures (Av. 85° F.) and high humidities (Av. R.H. 91 per cent) after lipid removal, trauma and the instillation of 0.5 ml. of

an undiluted 24-hour broth culture of *Pseudomonas aeruginosa*. Cultures of the secretions present in the ear canals were taken and morphologic examinations made at two, three or four-day intervals for 15 days.

In six of the seven ears marked to moderate morphologic changes (*viz.*, crusting, erythema and exudate) were present on the second day and persisted in five of the seven ears through the fourth day. Dryness of the skin of the ears of six of the cats was noted. All ears had returned to normal or

TABLE V.—EXPERIMENT E.

Survival of Beta-type Hemolytic Streptococcus in the External Auditory Canal of the Cat Under Conditions of High Temperatures and Humidities.
Av. T. = 89° F. Av. R.H. = 99%

		Days Following Contamination	
Cat	0	1	2
31	β-Str.	*	*
32	β-Str.	*	*

*No growth of contaminant.

near-normal appearance, but the ear cultures remained positive for Pseudomonas on the fifteenth day, when the experiment was terminated (see Table VI).

Experiment G.

It was postulated that if the lipid covering of the ear canal was removed, the skin traumatized and the ears exposed to high temperatures and high relative humidities, *Beta-type Streptococci* might persist for longer periods of time than was shown in *Experiment E.*

One ear canal of each of two cats was traumatized, the lipid surface covering removed and 0.5 ml. of an undiluted 24-hour broth suspension of *Beta-type Streptococcus* introduced. Five-tenths ml. of 10^{-6} dilution of a 24-hour broth culture of *Ps. aeruginosa* was instilled into the contra-lateral ears of both the animals. The cats were placed in a hot, moist environment (Av. T. 86° F.; Av. R.H. 98 per cent).

Despite the introduction of the additional factors, no streptococci were recovered on the first or second day. A luxuriant

TABLE VI.—EXPERIMENT F.

Survival of Pseudomonas (Undiluted) and Morphologic Changes of Skin of the External Ear of the Cat Under Conditions of Lipid Removal, Trauma and Elevated Temperatures and Humidities.

Av. T. = 85° F. Av. R.H. = 91%.

		Days Following Contamination											
		0		2		4		7		11		15	
Cat	Ear	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.
28	R	N	Ps.	R 3+ C 2+ X 2+	#	R + C 4+ X 3+	#	D C ±	#	D N	#	C ±	#
28	L	N	Ps.	R 3+ C 3+ X 3+	#	R 2+ C 4+ X 2+	#	D C ±	#	D N	#	C ±	#
29	R	N	Ps.	R 3+ C 2+ X 3+	#	D C +	#	D C 2+	#	N	#	N	#
29	L	N	Ps.	R 2+ C 2+ X +	#	D R 2+ C 4+	#	D R + C 3+	#	C +		C 2+	#
30	R	N	Ps.	R 2+ C + X 3+	#	R 2+ C 4+	#	D R 2+ C 4+	#	D C ±	#	C ±	#
30	L	N	Ps.	R 4+ C 3+ X 3+	#	D C +	#	R 3+ C 4+	#	C ±	#	N	#
46	R	N	Ps.	C 2+ X +	#	R 2+ C 2+ X 2+	#	*	*	R + C 3+ X 3+	#	C ±	#

= Growth of Pseudomonas. R = Erythema. C = Crusting. X = Exudate. D = Dryness. N = Normal.
* = No observations.

growth of the Pseudomonas was obtained on the first and second day in the ears in which it had been instilled (see Table VII).

Experiment H.

In this experiment it was considered desirable to determine the effects of low temperatures (Av. 61° F.) and low relative

TABLE VII.—EXPERIMENT G.

Influence of Lipid Removal, Trauma, High Temperatures and High Relative Humidities on the Survival of Pseudomonas aeruginosa (10^{-6} Dilution) and Beta-type Streptococcus in the External Auditory Canal of the Cat.

Av. T. = 86° F. Av. R.H. = 98%.

		Days Following Contamination		
Cat	Ear	0	1	2
25	R	Ps.	4+	4+
25	L	Str.	*	*
26	R	Str.	*	*
26	L	Ps.	4+	4+

*No growth.

TABLE VIII.—EXPERIMENT H.

Effects of Low Temperatures and Humidities Upon the Bacterial Flora and Morphology of the Cat External Auditory Canal.

Av. T. = 61° F. Av. R.H. = 51%.

Cats	Ears	Period of Observation	Bacterial Flora	Morphology
2	3	7-15 Days	Unchanged	Unchanged
6	6	15 Days	*	Unchanged

* = No cultures obtained.

humidities (Av. 51 per cent) on the morphology and bacterial flora of the cat meatus. Two cats (three ears) were observed for a period of seven to 15 days, while six cats (six ears) in a second group* were observed for 15 days.

As noted in Table VIII, no morphologic changes were observed in either group, and the bacterial flora remained unchanged in the first group. No cultures were obtained in the second group of animals.

*In these groups are included the untreated control ears of other experiments performed at these same temperatures and humidities.

Experiment J.

Undiluted suspensions of *Pseudomonas aeruginosa* have been shown to persist and morphologic changes have occurred in the external auditory canal of the cat for long periods under conditions of high temperatures and humidities. This experiment was designed to determine whether *Ps. aeruginosa* would similarly persist and morphologic changes occur in the cat meatus in a cooler and drier environment.

The external auditory canals of five cats (five ears) were contaminated with 0.5 ml. of an undiluted 24-hour broth suspension of *Ps. aeruginosa*. The animals were then placed in an environment of lowered temperatures and humidities (Av. T. 56° F.; Av. R.H. 50 per cent). Cultures of all ears were taken at various intervals for 17 days.

In all of the contaminated ears, the organisms were recovered in large numbers through the eighth day, but a rapid reduction occurred thereafter, so that only two ears showed any growth on the seventeenth day. Minimal skin changes were observed on the eighth day with one exception, and most of the changes had subsided by the fourteenth day (see Table IX).

Experiment K.

It has been shown that morphologic changes are less after Pseudomonas contamination in a lowered environmental temperature and humidity, but that there is little effect upon the persisting exogenous bacterial flora. To observe the changes which occur to the skin of the cat meatus after lipid removal, trauma and the instillation of *Pseudomonas aeruginosa* under cool, dry conditions the following experiment was conducted:

Three cats (six ears) were contaminated with 0.5 ml. of an undiluted 24-hour broth suspension of *Ps. aeruginosa* after trauma and removal of the surface lipids. The animals were placed in a cool, dry environment (Av. T. 58° F.; Av. R.H. 51 per cent) for a period of 15 days. Cultures of the secretions of the ear canal and examinations of the skin lining the canals were made at two, three or four-day intervals.

In all of the ears, the skin of the ear canal showed varying degrees of dryness, crusting, erythema and exudate on the

TABLE IX.—EXPERIMENT J.

Survival of Ps. aeruginosa (Unidluted) and Morphogic Changes in the External Auditory Canal of the Cat Under Conditions of Low Temperatures and Humidities.

Av. T. 56° F. Av. R.H. 50%.

		Days Following Contamination											
		0		4		8		12		14		17	
Cat	Ear	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.
45A	L	N	Ps.	C +	4+	N	4+	N	4+	N	+	N	+
37	R	N	Ps.	C ± X 4+	4+	C + X 2+	4+	C ± R +	4+	R +	4+	N	2+
38A	L	N	Ps.	D	4+	C ±	4+	N	+	N	+	N	*
39A	R	N	Ps.	D	4+	N	4+	N	2+	N	3+	N	*
40A	L	N	Ps.	N	4+	N	4+	N	±	N	*	N	*

* = No growth of Ps. aeruginosa. N = Normal. D = Dry. X = Exudate. R = Erythema.

TABLE X.—EXPERIMENT K.

Survival of Pseudomonas (Undiluted) and Morphologic Changes Produced in the External Auditory Canal of the Cat Under Conditions of Lipid Removal, Trauma, Low Temperatures and Humidities.

Av. T. = 58° F. Av. R.H. = 51%.

		Days Following Contamination											
		0		2		4		7		11		15	
Cat	Ear	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.	Morph.	Bact.
32A	R	N	Ps.	R 4+ C 2+ X 3+	4+	R 4+ C 4+ X 3+	4+	D R 2+ C 4+	4+	C ±	4+	C ±	4+
32A	L	N	Ps.	R 2+ C 2+ X 3+	4+	R 4+ C 4+ X 4+	4+	D R 3+ C 4+	4+	C +	4+	C ±	4+
33	R	N	Ps.	R 3+ C 2+ X 2+	4+	D C +	+	D C +	•	N	•	D	•
33	L	N	Ps.	R 3+ C 3+ X ±	4+	D R 2+ C 2+	4+	D C ±	4+	D	4+	N	2+
34	R	N	Ps.	R 3+ C 3+ X +	4+	D C +	4+	C +	4+	D	4+	N	+
34	L	N	Ps.	R 2+ C 2+ X ±	4+	C +	4+	D C ±	4+	R ±	4+	N	4+

R = Erythema. C = Crusting. X = Exudate. D = Dry. N = Normal. • = No growth.

second day. Morphologic changes were strikingly decreased in four of the ears on the fourth day, were less in all ears on the seventh day and minimal findings were present on subsequent examinations. On the other hand, Pseudomonas colonies were cultured from all ears through the fourth day and from seven of the eight ears through the balance of the experiment (see Table X).

DISCUSSION.

The inadequacy of the techniques for obtaining precise serial estimates of the number and variety of the bacteria implanted into the animal external auditory canal is recognized. Preliminary studies were performed in an effort to find more satisfactory methods, but the peculiar and highly variable anatomical configuration of the meatus made these more accurate procedures clinically and experimentally impractical. In an effort to reduce possible errors in interpretation, experiments were set up in duplicate and, although not always included in the data, controls were introduced in all the studies.

It was found necessary to perform a survey of the bacterial flora in the normal external auditory canal of the cat in order to determine whether the organisms which are cultured from acutely infected human ear canals were present in the endogenous flora of these animals. Upon comparison of the flora of the human and animal ear canals, there is noted a striking similarity. Conspicuously absent is the pseudomonas group of bacteria in the flora of both humans and animals. This observation is of particular interest since *Pseudomonas aeruginosa* has been shown to be the exogenous organism most frequently cultured from acute diffuse external otitis.

Because numerous investigators have demonstrated that normal intact human skin in other parts of the body rapidly eliminates implanted exogenous bacteria in a matter of minutes or hours, it was surmised that this same phenomenon would occur in the meatus of the experimental animal. On the contrary, *Ps. aeruginosa* introduced into the external auditory canal of the cat exposed to a hot, humid environment persisted for as long as 18 days. This finding substantiates

our previous observations.[32] The results of these experiments duplicate the experience of the otologists in tropical and subtropical regions, who report the persistence for indefinite periods of pseudomonas organisms in the meatus of patients with "cured" diffuse external otitis. They are not in agreement with the observations of Shelley and Perry,[28] who were unable to recover *Ps. aeruginosa* which had been introduced one week previously into the ear canals of human subjects.

It was anticipated that *Ps. aeruginosa* in dilute suspensions would survive for shorter periods when introduced into the healthy cat meatus. The diluted suspensions of *Ps. aeruginosa* appeared to increase to a maximum just as rapidly as the undiluted cultures for the first six to eight days, while the undiluted cultures seem to reduce in numbers more rapidly thereafter. Diluting the cultures did not appear to exert an appreciable influence upon the rapidity with which the bacteria were completely eliminated. The results appear to confirm the theory that bacterial infection of the ear canal is not necessarily caused by overwhelming contamination, but rather that only a few virulent organisms implanted on a fertile skin substrate will rapidly multiply in the ear canal and institute infection in a susceptible individual.

In addition to the persistence of the contaminating bacteria, gross morphologic changes (crusting, erythema, edema and exudate) occurred after the introduction of *Ps. aeruginosa*. The changes were not present in all the infected animals and they varied in severity, thus simulating the clinical findings in human external otitis. These observations conflict with previous studies[30,31,32] in which we, as well as other investigators, were unable to produce disease of the external ear or only minimal microscopic changes in the skin by the mere instillation of fungi or bacteria. This difference may be a consequence of uncontrolled factors, such as the virulence of the contaminating organism and individual susceptibility of the experimental animal.

Although no experiments were designed to test the virulence of pseudomonas cultures, it was noted that frequent subculturing of the stock strains resulted in attenuated organisms which failed to survive or produce morphologic changes in

the cat ear; consequently, it was found necessary to discard some strains of *Ps. aeruginosa* after a period of growth on artificial media.

Individual differences in susceptibility of the experimental animals were also demonstrated throughout the experiments. Some animals appeared to be highly sensitive to the infecting bacteria, with consequent prolonged survival of the organisms and severe morphologic changes. Other animals used in these studies were apparently resistant regardless of environmental conditions or combinations of factors. Further studies are desirable concerning virulence and susceptibility of both animals and humans to *Ps. aeruginosa*.

Our observations failed to substantiate the hypothesis that exposure of our experimental animals to hot, moist atmospheric conditions would make the skin of the ear more susceptible to infection with exogenous organisms.[11] Gross morphologic changes or alterations in the endogenous bacterial flora of the uncontaminated external auditory canal did not occur during exposure of cats to markedly elevated or moderately lowered temperatures and humidities; however, when cats with infected ears were transferred from a hot, humid environment to a cool, low-humidity room, no startling reduction in the number of bacteria was noted, although some improvement of the skin morphology occurred.[29]

High temperatures and high relative humidities were not found to be the sole factors responsible for the prolonged survival of implanted exogenous bacteria or the concomitant skin changes, since the organisms were shown to persist in some animals for long periods at low temperatures and humidities. Some of the data, however, would indicate that at high temperatures and humidities the growth of the *Ps. aeruginosa* was more luxuriant than when the animals were kept in a cool, dry environment.

Various reports have shown that there is a distinct difference in the ability of healthy, intact skin to eliminate bacteria belonging to the Gram-positive and Gram-negative categories. In our series of experiments, as in other skin areas, it was noted that streptococci failed to persist even for very short

periods. The suspension of coagulase-positive *M. aureus* was not eliminated as rapidly as the streptococci, but much more rapidly and completely than any of the Gram-negative bacilli tested. A warm, moist atmosphere did not appear to be conducive to the survival of the Gram-positive bacteria, nor did removal of the fatty covering or trauma contribute to persistence of the organism.

In this study it was not possible to test a sufficiently large number of animals, or to control the many variables in such a manner that statistical evaluation of the data could be performed. Should further investigations of the influence of temperature, humidity, trauma and lipid removal on the survival of exogenous organisms be undertaken, then the number of animals used should be increased or the number of variables reduced to make statistical studies possible.

CONCLUSIONS.

The endogenous bacterial flora of the healthy cat meatus is very similar to that of the normal human external auditory canal.

Elevated or lowered temperatures and humidities do not alter the endogenous flora or produce any change in the morphology of the skin of the cat ear canal.

Exogenous Gram-negative bacteria, particularly the *Ps. aeruginosa*, will survive for prolonged periods in the external auditory canal of the cat at low or high temperatures and humidities. The Gram-positive organisms, *i.e.*, *Beta-hemolytic Streptococcus* and *M. aureus*, are eliminated after a relatively short period.

Suspensions of *Ps. aeruginosa* introduced into susceptible cat ear canals will produce morphologic skin changes at high temperatures and humidities.

Some of the data suggest that, in a cool, low-humidity environment, there may be less luxuriant bacterial growth, a shorter survival time and fewer morphologic changes after instillation of Gram-negative bacilli.

Trauma to the skin of the cat external auditory canal and

removal of the surface lipids did not appear to alter the survival time of the exogenous organisms.

The concentration of organisms instilled into the cat ear (within the range tested) is not an important factor in the length of survival of this organism or the severity of the morphologic changes produced.

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STUDIES OF FACTORS CONSIDERED RESPONSIBLE FOR DISEASES OF THE EXTERNAL AUDITORY CANAL.*

II. Evaluation of Temperature and Humidity as They Influence the Amount of Ether-Soluble Substances in the External Auditory Canal.

ELIZABETH S. BAUMANN, B.A.,
CARL F. GESSERT, Ph.D.,
and
BEN H. SENTURIA, M.D.,
St. Louis, Mo.

INTRODUCTION.

It is generally accepted that the highest incidence of diffuse external otitis occurs in hot, humid climates, while there are comparatively few cases observed in cool, dry environments. It has been suggested that an alteration of the lipid skin cover, caused by conditions of high temperature and high humidity, may play a role in the production of this disease.[1]

Studies have been made of the effects of temperature and moisture on the lipid covering of the skin of various other parts of the body,[2-9] but there is a paucity of data pertaining to these effects on the lipids of the skin of the ear canal.[10] Although determinations were previously made in this laboratory on the amounts of ether-soluble substances (ESS)† which are found in the external auditory canals of various groups of humans,[11] none of the data were obtained under controlled environmental conditions. The present experiments, therefore, were designed to measure ESS in the external auditory

*From the Washington University School of Medicine, Department of Otolaryngology, St. Louis, Mo.

†Ether-soluble substances (ESS) are the lipids extracted with ether from cerumen specimens.

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canals of animals, which could be maintained in environments of controlled temperature and humidity. In this way, an evaluation could be made of the effects of temperature and humidity on the lipid film of the skin of the cartilaginous meatus.

LITERATURE REVIEW.

Some workers are convinced that the lipid film on the surface of the skin acts as an important barrier in preventing the extension of bacteria into or through the epidermis. The lipid cover has been shown to have bactericidal and fungistatic properties.[12-17] According to Rebell et al.,[17] Gram-negative bacilli survived for much longer periods on skin from which the lipids were removed by thorough washing with organic solvents than on skin on which the lipid cover had been left intact. Arnold and his co-workers[13] found that a coating of grease or dirt on the skin of hands allowed such bacilli to remain viable for long periods of time. The findings of these two investigators are not necessarily contradictory since in one case the skin lipids are removed, and in the other case they are covered up so that they do not come in contact with the bacteria.

The influence of environmental temperatures and skin moisture on the amount and distribution of lipids on the skin surface has been considered by many investigators.[2-9] The theory has been advanced that at high temperatures and on moist skin the sebum may become fluid[6-9] and in this manner fail to provide a protective cover.[3]

Mole[18] and Blank[19,20] have demonstrated that the stratum corneum will take up moisture from an environment having a high relative humidity. Blank showed that cornified epithelium absorbed increasing amounts of moisture, particularly at relative humidities above 80 per cent. It is conceivable, therefore, that when exposed to high humidities, the keratin in and around the orifice of the apo-pilosebaceous unit absorbs moisture, thereby swelling and causing a decreased flow of lipids to the skin surface.[21-25]

METHODS AND TECHNIQUES.

Animals. The cat and pig have been shown to have apocrine and sebaceous glands in the skin of the ear canal similar to those of the human.[26-28] The cat was chosen as the most suitable and available experimental animal. The difficulty of handling the cat, however, made it desirable to use in some of these experiments a more tractable animal, such as the rabbit, which has in the skin of its external ear canal numerous sebaceous but no apocrine glands. In two experiments cats and rabbits were used simultaneously, so that data from these two species could be compared.

Maintenance. Experimental animals were housed in individual metal cages, and all were offered a balanced diet.

Experimental Rooms. In the hot room the desired temperature was achieved by use of electric heaters controlled by thermostat,* which supplemented the centrally supplied steam heat. An automatically controlled humidifier† maintained humidities within the planned range. Conditions of low temperature and humidity were achieved in the cool room by use of a room air-conditioner‡ and a dehumidifier.§

Anesthesia. It was frequently necessary to anesthetize the cats. This was done by intrathoracic injection of pentobarbital sodium, approximately 12 mg. per pound of body weight. A few cats were anesthetized by intraperitoneal injection, but the intrathoracic route was found to be more satisfactory, in that the animals were subdued with less struggle and recovery was much faster, usually occurring within four to six hours. When no anesthetic was used, the cats were managed by wrapping them in a large square of heavy denim cloth, and the rabbits were restrained in a wooden box designed for that purpose.

Collection and Analysis of Specimens. Specimens for the determination of total ESS were obtained by wiping the cartilaginous meatus in a prescribed manner with two cotton

*Two Chromolon electric heaters, thermostatically controlled by a Mercoid Switch.

†Walton Humidifier, Model W.F.

‡General Electric Room Conditioner, ¾-ton.

§Frigidaire portable dehumidifier.

swabs moistened with ether.[11] The swabs were extracted with redistilled ether in a micro-Soxhlet apparatus and the amounts of ESS were determined by a colorimetric method adapted to micro-scale.[29]

Samples for the determination of the percentages of lipid and protein were collected and analyzed by methods previously described.[30]

In all experiments a casual* specimen was taken from each ear to be studied. For those experiments in which a zero-day† specimen was obtained, the order of the procedure was: *a.* Casual specimen taken; *b.* ear canal and auricle cleansed with three cotton swabs moistened with ether; *c.* zero-day specimen taken.

EXPERIMENTAL PROCEDURES AND FINDINGS.

Preliminary Experiments on Cats and Rabbits.

Several pilot studies were conducted to examine the ear secretions of the animals without control of environmental temperature and humidity. The normal (ambient) animal room temperatures and humidities were allowed to prevail.

Experiment A.

The percentage of protein and lipid in the cerumen of cats was investigated. Casual specimens were collected from both ears of two cats and the ears were cleaned with ether-moistened swabs. Fresh samples‡ were taken at two and 12 days after cleaning.

As shown in Table I, the percentage of lipid in the first fresh samples (taken after cleaning) was higher than in the casual cerumen, while the percentage of protein was generally lower. By the twelfth day the percentage composition of the cerumen of each cat ear tended to revert to the composition of the corresponding casual specimens. In these character-

*Casual specimens are the samples obtained from the unprotected skin surfaces of the ear canal at the beginning of the period of observation, without previous cleansing or treatment of the canal.

†Zero-day refers to the initial day of any series of observations. Specimens designated as zero-day samples were collected immediately after cleansing the ear canal.

‡A fresh sample is a specimen collected during the period of observation at any time after zero-day.

istics, the findings in cats were similar to those for humans, as reported by Chiang et al.[31]

Experiment B.

The amounts of ESS obtained from the external auditory canals of cats and rabbits were compared. Casual and zero-day specimens were taken from one ear each of two cats and two rabbits. At intervals of four, eight and 15 days, specimens were obtained from the same ears.

The data in Table II indicate that one can expect the same

TABLE I.—EXPERIMENT A.

Percentages of Lipid and Protein in Cat Cerumen.

		Casual Specimens		Day of Collection 2		12	
Cat	Ear	Lipid	Protein	L	P	L	P
2	R	46.9	22.9	54.8	14.9	41.3	15.1
2	L	47.5	30.6	56.2	15.8	46.8	19.9
3	R	32.1	32.7	53.0	20.6	32.4	24.3
3	L	36.3	41.8	44.3	38.1	28.4	39.4

order of magnitude in the amounts of ESS obtained from the ear canals of cats and rabbits. These amounts are generally larger than the amounts obtained from humans, as reported by Chiang et al.[11] As previously observed with humans, by the fifteenth day replacement totals (RT)* exceeded their respective casual amounts.[11]

Despite the histological differences of the skin of the cat and rabbit meatus, the findings here regarding average daily replacements (ADR)† and RT's are similar in these two species. The absence of apocrine glands in the skin of the rabbit did not appear to influence the amount of ESS recovered in these few ear canals.

Experiment C.

Because the cleansing procedure used on zero-day might

*Replacement total (RT) at any given time is the total amount of ESS that has been extracted from all the fresh specimens collected by that time from a single ear. This does not include zero-day amount.

†The average daily replacement (ADR) is a measure of the rate of lipid renewal on the skin surface during any interval between successive collections. It is calculated by dividing the amount of ESS in a fresh specimen by the number of days in the interval since the preceding collection.

introduce an uncontrolled factor either by being traumatic to the skin of the ear canal or by influencing the delivery of lipids to the surface, this experiment was designed to determine whether or not the cleansing had any effect on the amounts of ESS subsequently obtained.

In one ear of each of two rabbits a casual specimen was obtained, the canal was thoroughly cleansed, and a zero-day specimen was taken. In the contra-lateral ears casual specimens were taken, but no cleansing was performed and no zero-day specimens were obtained. At intervals of three

TABLE II.—EXPERIMENT B.

Ether-soluble Substances in Cat and Rabbit Cerumen: A Comparison in Terms of Average Daily Replacements and Replacement Totals. (Expressed in Milligrams).

Animal and Ear	Casual Amount	Zero-day Amount	Days After Cleaning 4 ADR*	4 RT†	8 ADR	8 RT	15 ADR	15 RT
Cat 90 L	15.3	1.3	1.4	5.4	1.3	10.5	1.0	17.8
Cat 91 R	10.8	1.2	1.3	5.0	1.0	8.9	0.9	15.1
Rabbit 59 R	11.8	0.4	1.7	6.8	2.3	15.9	1.6	27.1
Rabbit 60 L	10.2	1.2	1.4	5.7	3.0	12.1	2.4	29.0

*Average Daily Replacement.
†Replacement Total (does not include zero-day amount).

seven and 14 days, specimens were taken from all ears (see Table III).

In the rabbit, thorough cleansing of the ear canal did not appear to influence the amounts of ESS which were obtained from the third day on. The technique for taking casual specimens evidently constituted a sufficient cleansing of the ear canal so that the additional cleansing had no effect.

Experiments on Cats and Rabbits Under Controlled Environmental Conditions.

Experiment D.

A comparison was made of the amount of ESS obtained from the ear canals of cats and rabbits kept under controlled environmental conditions.

Casual specimens were taken from both ears of two cats

and two rabbits; the animals were kept in a cool, dry room for seven days, and then in a hot, humid room for seven days. Specimens of ESS were taken on days 3, 5, 7 and 10, 12, 14. By measuring the amounts obtained on days 5, 7, 12, and 14,* it was possible to compare the data for two 2-day periods, under both environmental conditions (see Table IV).

Under the experimental conditions employed, the average amounts of ESS obtained from the ears of cats and of rabbits were somewhat greater when the animals were kept in the

TABLE III.—EXPERIMENT C.

Amounts of Ether-soluble Substances (in Milligrams) Found in Rabbit Ear Canals, with or without a Cleansing Procedure.

			Day of Collection			
Rabbit	Ear	Casual	Zero-day	3	7	14
65	R	6.0*	0.5	6.6	12.3	11.8
65	L	5.4		6.7	12.3	5.6
66	R	6.4		8.9	6.0	4.1
66	L	7.7*	2.3	8.5	4.2	4.3

*After casual specimen was taken, ear was cleaned with 3 cotton swabs dipped in ether.

hot, humid room (12th and 14th days) than when they were in the cool, dehumidified room (5th and 7th days).†

As in Experiment B, no difference was observed between the average amount of ESS obtained from the ears of cats and rabbits when both groups were maintained in the same environmental conditions.

Experiment E.

In order to cancel any undetermined effects that order of exposure and the factor of time might have had on the data of Experiment D, it was decided to reverse the environments with half of the animals.

Casual specimens were taken from one ear each of eight rabbits. For a period of 11 days, half of the animals were kept in a hot, humid room and the other half in a cool, low-

*Specimens from days 3 and 10 were not determined as they represented 3-day intervals.

†The significance of these differences was not evaluated statistically because of the limited number of animals.

humidity room. Then the animals were interchanged for a similar period of time. Specimens for total ESS were taken on days 7, 9, 11 and 18, 20, 22. By determining the amounts of ESS obtained on days 9 and 11 in one environment, and on days 20 and 22 in the other,* data were obtained for two 2-day periods of accumulated secretions in both environments (see Table V).

TABLE IV.—EXPERIMENT D.

The Amounts of Ether-soluble Substances (in Milligrams) Obtained from the Ear Canals of Cats and Rabbits Kept in Environments of Controlled Temperature and Humidity.*

		Day of Collection			
		5	7	12	14
Animal	Ear	Cool, dry room†		Hot, humid room‡	
Cat 1	R	6.7		5.8	6.1
Cat 1	L	5.0	5.7	5.6	7.4
Cat 2	R	5.7	7.1	6.6	9.1
Cat 2	L	8.0	6.5	8.0	11.8
Mean ESS		6.39		7.55	
Rabbit 3	R	6.3	6.1	9.2	7.1
Rabbit 3	L	4.8	5.2	7.6	6.6
Rabbit 4	R	4.4	4.4	6.4	5.3
Rabbit 4	L	5.1	7.3	7.5	5.7
Mean ESS		5.45		6.93	

*Dry and wet bulb temperatures were measured daily. Relative humidity was read from Relative Humidity Tables printed by Taylor Instrument Companies, Rochester, N. Y.

†Temperature: Av. 71° F. (range 69-74° F.). Relative Humidity: Av. 70% (range 64-74%).

‡Temperature: Av. 85° F. (range 84-88° F.). Relative Humidity: Av. 95% (range 93-98%).

A comparison was made between the data obtained from each rabbit ear during the time that the animal was in the hot, humid environment and that obtained from the same ear when the rabbit was in the cool, low-humidity room. When the data were compared, no significant difference was found between the amounts of ESS obtained in the two environments, under the experimental conditions employed.† The lack of a real difference in the amounts obtained was also reflected in the closeness of the means of 2-day accumulations in the two environments, *i.e.*, 6.29 and 6.53 (see Table V).

*Specimens on days 7 and 18 were not considered because they represented amounts accumulated for 7-day periods.

†Probability was much greater than 0.1 by the Wilcoxon signed-rank test for matched samples.[22]

Experiment F.

Since it seemed possible that the effect of a particular environment might not be immediately apparent, it was considered desirable to expose the animals to each environment for a longer period of time than had been done in Experiment E.

Cats were used in this study, whereas rabbits had been used in Experiment E. Casual specimens were taken from both

TABLE V.—EXPERIMENT E.

The Amounts of Ether-soluble Substances (in Milligrams) Obtained from Ear Canals of Rabbits Kept in Environments* of Controlled Temperature and Humidity.†

	Day of Collection			
Ear	9	11	20	22
	Hot, humid room‡		Cool, dry room§	
5 R	5.5	5.1	4.9	4.4
6 L	6.6	6.3	8.9	6.2
7 R	6.7	7.0	6.9	5.9
8 L	9.2	6.7	7.3	6.2
	Cool, dry room§		Hot, humid room‡	
9 R	7.9	5.9	5.5	5.0
10 L	6.6	5.6	8.1	6.9
11 R	7.7	5.9	8.4	4.1
12 L	5.6	4.8	7.7	5.6

Overall means of ESS for 2-day periods:

Cool, dry room ..... 6.29 mg.
Hot, humid room ..... 6.53 mg.

*Order of environmental exposure was reversed with half of the animals.
†See first footnote of Table IV.
‡Temperature: Av. 83° F. (range 79-85° F.). Relative humidity: Av. 91% (range 80-96%).
§Temperature: Av. 66° F. (range 60-69° F.). Relative humidity: Av. 56% (range 38-70%).

ears of each of six cats, which were divided into two equal groups, one being placed in a hot, humid room and the other in a cool, low-humidity room. Fresh specimens were taken at the end of each week for three weeks, then the two groups of cats were interchanged, and specimens were taken weekly for another three weeks. The data which were obtained on the amounts of ESS in all fresh specimens are shown in Table VI.

The data were examined in two ways. In one test, the data

from only one ear of each of the six animals were considered; and in the other, the data from both ears were added and used together. As in Experiment E, the hot, humid room data for each animal were compared with the cool, dry room data for the same animal. The overall means of the amounts of ESS obtained per ear in the period of a week were 14.5

TABLE VI.—EXPERIMENT F.

The Amounts of Ether-soluble Substances (in Milligrams) Obtained from the Ear Canals of Cats Kept in Environments* of Controlled Temperature and Humidity.†

	Day of Collection					
Ear	7	15	22	29	36	43
	Hot, humid room‡			Cool, dry room§		
14 R	23.6	14.2	16.1	15.0	17.3	20.6
14 L	12.8	ø	10.4	11.9	13.5	14.9
15 R	16.5	15.3	15.9	20.1	12.2	12.6
15 L	8.2	6.6	12.0	20.9	18.7	21.7
18 R**	(14.3)	(16.5)	(15.2)	ø	(40.0)	ø
18 L	16.5	13.2	16.6	23.1	18.1	21.4
	Cool, dry room§			Hot, humid room‡		
13 R	4.8	9.7	7.2	9.0	8.9	14.0
13 L	11.8	8.8	8.7	6.9	8.5	14.8
16 R	16.8	14.2	13.4	10.2	10.8	16.1
16 L	13.6	14.8	14.7	13.9	15.5	20.4
17 R	14.3	17.6	9.8	5.8	13.5	9.0
17 L	14.8	12.4	11.0	11.9	14.0	19.2

Overall means of ESS for weekly periods:

Cool, dry room ..... 14.5 mg.
Hot, humid room ..... 13.1 mg.

*Order of environmental exposure was reversed with half of the animals.

†See first footnote for Table IV.

‡Temperature: Av. 85° F. (range 82-88° F.) Relative humidity: Av. 92% (range 77-100%).

§Temperature: Av. 64° F. (range 51-70° F.). Relative humidity: Av. 58% (range 37-74%).

øSpecimen accidentally destroyed.

**None of the data pertaining to 18-R were taken into account because the data for this ear were incomplete.

mg. in the cool, dry room and 13.1 mg. in the hot, humid room. In both methods of examining the data, no significant difference was found between the amounts of ESS obtained in the two environments, under the experimental conditions employed.*

*Probability was greater than 0.1 by the Wilcoxon signed-rank test.[32]

DISCUSSION.

A completely satisfactory method for collecting specimens which contain all of the ether-soluble matter that is present in an ear canal at a given time has not yet been devised. In view of the variation in size and anatomical configuration of the external auditory canal that prevails from one animal to another, there is, very likely, some variation in the degree of completeness with which the total ESS present in a meatus are collected with our ether-moistened swab technique.

Tests have been made to determine the feasibility of collecting the lipid matter by instilling several successive, measured portions of organic solvent, *i.e.*, ether and ethanol, into the ear canal, recovering the solvent solution with a syringe and a small piece of flexible tubing, then measuring the lipid in these solutions. It was found, however, that in the cat, ether used in this manner acted as a strong irritant, whereas ethanol was unsatisfactory as a solvent. Although the swab method of collecting specimens of ESS was far from being ideal, it seemed to be the more satisfactory for the purposes of these studies.

The amount of lipid (ESS) which was found in the meatus in both cats and rabbits revealed neither an increase nor decrease when the animals were kept in a hot, humid environment, as compared with a cool, low-humidity environment. The protected position of the external auditory canal may afford a degree of insulation sufficient to prevent any large fluctuations in air temperature in the meatus, and, therefore, also may prevent any change in the physical characteristics of the skin surface film. It is also conceivable that even though the viscosity of the skin surface lipids may be lowered by an increased temperature, the anatomical configuration of the cartilaginous meatus would prevent the lipids from flowing to the perimeatal regions.

It is still possible that environmental temperature and humidity do have an important role in determining susceptibility of the skin of the auditory canal to infection. It appears, however, from our data, that these factors do not exert their influence through a regulation of the amount of lipid

coating which is present on the skin surface in the external ear canals of the rabbit and cat.

It is of interest that the average amounts of ESS that were obtained from the external ear canals of cats and rabbits which were kept in the same environment did not appear to differ, even though there are notable histological differences in the skin of the ear canals of the two species. The presence of apocrine glands in the skin of the cat meatus and their absence in the rabbit had no measurable effect on the quantities of ESS found.

CONCLUSION.

The quantity of lipid material (measured as ESS) which is found in the ear canal of the cat or rabbit is not significantly different whether the animal is kept in a hot, humid environment, or in a relatively cool, low-humidity room.

ACKNOWLEDGMENTS.

The authors express appreciation to Charles D. Carr for technical assistance and advice and to Dorothy L. Baldwin and Nancy Hellman for secretarial and editorial aid.

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THE GOULD AWARD.

The Gould Award is presented annually for outstanding research in laryngology to encourage and reward fundamental investigations in this field.

The International Committee for the Gould Award announces the selection of the recipient for the year 1958: Prof. FumioNakamura, M.D., Kyoto Prefectural Medical College, Kyoto, Japan, for his electrophysiologic studies of laryngeal function.

The International Committee for the Gould Award for 1959 will consist of Sir Victor Negus, 149 Harley St., London, W.1; Prof. Cotoji Satta, No. 111 Morikawa-cho, Bunkyo-ku, Tokyo; and Hans von Leden, M.D., Medical Director, The William and Harriet Gould Foundation, 30 North Michigan Avenue, Chicago 2, Illinois.

The amount of the Award has been increased to $300.00.

CONGENITAL BILATERAL COMPLETE BONY CHOANAL ATRESIA.

JACK A. RUBIN, M.D.,

Winnipeg, Manitoba.

The following case of choanal atresia as an emergency in the newborn, is reported:

CASE REPORT.

K.V., a white female, newborn, was noted to have respiratory distress after a spontaneous delivery. Birth weight 6 lbs., 14 ozs. The pre-natal course had been uneventful. Direct laryngoscopy and chest examination revealed no abnormalities. An attempt to pass a nasal catheter via both sides of the nose was unsuccessful. A diagnosis of congenital bilateral choanal atresia was made.

The infant was placed in an incubator and given oxygen. Repeated nasal suctioning was necessary to remove the thick mucoid discharge, which kept reappearing at the anterior nares. It was noted that the child's color was good, and the respiratory difficulty disappeared when the patient cried; however, while feeding or lying quietly in its crib, definitely labored breathing, blue spells and indrawing of the intercostal and supraclavicular spaces would occur. The breathing was "noisy" and labored at all times, except when crying. X-rays of the skull did not show air in the nasal cavities, and for some reason contrast media was not instilled into the nasal cavities.

The infant was treated with oxygen and repeated nasal suctioning for the first 48 hours. Feeding was poor, and the infant began to show signs of dehydration and progressive asphyxia.

Otolaryngological consultation at age two days confirmed the diagnosis of bilateral complete bony choanal atresia. Neither catheter nor metal probe could be passed through the thick bony partition, via the anterior nares. Considering the state of the infant, an emergency procedure was done as follows: After unsuccessfully attempting to push a trocar through the partitions, a small gouge and mallet was used to punch an opening through both bony choanal walls. The results immediately following this were dramatic. The child fell asleep with no respiratory distress for the first time, and breathing through the nose was possible.

Following this, feeding and sleeping were normal; however, because of noisy nasal breathing, both choanal openings were enlarged slightly intranasally five days later. A polyethylene tube was placed in the nose through the choanal opening; however, the tubing had to be removed within 24 hours, as it interfered with nasal breathing. Because of a very shallow nasopharynx, the inner opening of the tube was partially obstructed.

The infant was discharged from the hospital at two weeks of age.

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At home, the mother was required to suction the nose every four hours. For the next four months, the infant would feed, breathe and sleep well for one week at a time. As a result, the patient was seen regularly at the office for thorough suctioning and dilatation of the choanal openings. At eight months of age, a revision was done by the intranasal route, using a small biting forcep, gouge and chisel. The edges of the opening were removed by this means, resulting in a good sized passage. Following this, the child has been breathing solely through the nose, and suctioning was necessary only once daily in the morning. Feeding proceeded normally, and the infant slept through the night with quiet respirations.

When last seen at the age of two years, the child was completely normal in all habits: feeding, sleeping and breathing through the nose. The breathing was quiet, and the choanal openings were unchanged. Examination of the ears, pharynx, sinuses and nasal cavity showed no abnormalities.

A further revision may be done in the future; (the time will depend upon the progress of the child, whereby the remainder of the choanal bony plate will be removed). A transpalatine approach as advocated by Owens, etc., will probably be used. The easier surgical approach employed in this case was thought advisable because of the age of the infant.

603 Boyd Bldg.

ANNOUNCEMENT.

The Annual Spring Meeting of the Alumni Association of the New York Eye and Ear Infirmary will take place April 20-23, 1959, at the Infirmary.

Symposia will be offered on Headache; Allergy and Immunology in Otolaryngology; Diagnosis and Treatment of Laryngeal Conditions; Hearing Rehabilitation; and Rhinoplasty. In addition, there will be a closed circuit television demonstration of Head and Neck Surgery.

Additional information may be obtained by writing to Dr. John R. Finley, Secretary, Alumni Association, 218 Second Avenue, New York 3, N. Y.

PROCAINE CONVULSIONS.

JOHN KEOHANE, M.D.,

Stettler, Alta, Canada.

Toxic reactions to local anesthetic drugs may be of a cardio-vascular system depressant, or a central nervous system stimulating type. The latter may also be followed by the former more serious type of reaction.

The entire subject of toxic reactions to local anesthetics, whether used by topical application or infiltration of tissues, has been very well reviewed in two recent publications.[1,2] The following report is, however, of interest since it concerns a toxic reaction to procaine in a dose about one-quarter of the generally accepted maximum safe dose. Procaine is also thought to be one of the safest local anesthetics.

N. D., a 26-year-old man, was admitted to the hospital on May 13, 1958, for a tonsillectomy under local anesthesia the following morning. At 10:00 P.M. the evening before his operation, he was given Seconal, 1½ gr. orally. Next morning he had Seconal 1½ gr. two hours preoperatively, followed by ¼ gr. morphine and 1/200 gr. atropine one hour preoperatively. A few minutes after spraying his throat with a small amount of 2 per cent pontocaine solution, both peri-tonsillar regions were infiltrated with a total of 25 cc. of 1.00 per cent procaine with two drops of epinephrine, 1/1000 solution, added. About two minutes after the last of the local anesthetic had been injected the patient became restless and excitable. He was immediately put into a horizontal position and directions given to the operating room nurse to get a solution of Pentothal ready. About 30 seconds later his face began to twitch, and this was soon followed by a severe generalized convulsion.

As soon as the Pentothal was available (approximately one minute after it was requested) the patient was given 10 cc. of a 2.5 per cent solution intravenously (250 mg.). Meanwhile oxygen was given from an anesthetic machine. The convulsions were quickly controlled. Pulse, respiration, blood pressure and color were soon within normal limits. An intravenous drip of 5 per cent glucose in water was started, to have ready access to a vein. After observing the patient for a little longer the oxygen was discontinued, and he was transferred back to bed. A solution of Pentothal in a syringe and the anesthetic machine was brought to the patient's bedside in case of further trouble.

A little over an hour-and-a-half later I was urgently called to see the patient. It took me approximately two minutes to get to his bedside. He was having a severe convulsion, which had commenced two minutes previously (when he began to recover from the effects of the Pentothal) and showed no sign of abating. A further 8 cc. of Pentothal (2.5 per cent)

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controlled the convulsions, but the patient immediately stopped breathing. He was kept on controlled respirations for approximately one hour when spontaneous respirations returned. During the prolonged period of respiratory paralysis the patient's pulse rate went up a little and on occasions became somewhat irregular. His general condition, however, remained very good. He was given 4 cc. of Coramine intravenously after 30 minutes of apnea and this was repeated about 15 minutes later. It appeared to have little effect. One hour later he was able to answer questions but was still quite drowsy. When seen later that day he was fully conscious and felt quite well. He was discharged from the hospital next day, and I hope to do a tonsillectomy with a general anesthetic soon.

This man was a healthy farmer. Neither he nor his family had any previous history of epilepsy. He had a local anesthetic for a dental extraction two years ago with no reaction.

SUMMARY.

A case of convulsions after infiltrating the peri-tonsillar tissues with 25 cc. of 1.00 per cent procaine with two drops of epinephrine, 1/1000, is reported. Although the convulsions were controlled with Pentothal they returned when its effect began to wear off, approximately one-and-a-half hours later. They were again controlled by Pentothal, and after a period of apnea of one hour's duration the patient made an uneventful recovery.

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The Medical Center.

ABSTRACT OF THE PROCEEDINGS OF THE SEVENTY-NINTH ANNUAL MEETING OF THE AMERICAN LARYNGOLOGICAL ASSOCIATION.

San Francisco, Calif., May 19-20, 1958.

HARRY P. SCHENCK, M.D.,
President.

SAMUEL SALINGER, M.D.,
Abstract Editor.

GROUND SUBSTANCE IN THE NOSE IN HEALTH AND INFECTION.

EUGENE S. HOPP, M.D.,
and
HELEN F. BURN, M.S. (By Invitation).

These authors present the evidence thus far accumulated by themselves and others relating to the permeability of the ground substance in nasal tissues under varying conditions and the factors which permit certain bacteria to penetrate and spread. Spreading factors, notably hyaluronidase, seem to be more abundant in staphylococci than in most streptococci, which enhances their invasive potentialities. The hyaluronidase possesses the ability to depolymerize the hyaluronic acid in connective tissue, thus favoring the spread of infection. These findings resulted from comparative multiple stain techniques of serially sectioned biopsies of turbinates from normal individuals and from patients with infection. The authors conclude that since hyaluronidase is most active in the range of normal, slightly acidic nasal pH, the accepted

concept of alteration of nasal pH to the alkaline side in nasal infection may be a defense mechanism and, therefore, the effect of the early stage of infection rather than the cause.

DISCUSSION.

Dr. Aubrey G. Rawlins brought out some of the relationships between the corticosteroids and the ground substance whose density is regulated by the pituitary-adrenal axis. The efficiency of this axis may be one determining factor in the invasiveness of certain organisms. Dr. Hopp has furnished good evidence that hyaluronidase-producing bacteria are often more invasive than non-producers, and this would be an important factor in many nose and throat infections. The authors have shown how the spreading factor loosens the basement membrane under the epithelium, resulting in easier invasion by organisms.

Not much is known as to whether or not there is any spreading factor in the normal nose and throat mucosa; however, it must be assumed that its precursor is there, since the existence of hyaluronidase and mucolytic enzymes in the connective cells has to be postulated if equilibrium of the ground substance is to be explained.

Dr. Hopp mentioned the anti-spreading factor of which there are two types: the antibody which is specific and the heparin-like substance which is non-specific and is high in the blood stream in many diseases of a serious nature.

The authors have well emphasized the dual features of infection namely, the virulence and characteristics of the infecting organism and the quality of the ground substance of the host.

Dr. George Kelemen showed several electron microscopic slides of tonsil tissue which at high magnification (30,000) depict the elements in the collagenous material, the fibrillar structures and the relationship of the epithelial cells to each other. Since these are joined together by intercellular bridges it can be seen how the lymphocytes have to push their way through by breaking down these bridges.

Electron microscopy can contribute much of our knowledge of tissue reaction to infection by bringing out the finer anatomic details of the various elements under varying conditions.

Dr. Hopp in closing stated, in response to Dr. Rawlins' query, that in 1931 filtrates were taken from the normal nose as well as from individuals having a cold; and it was demonstrated that there were spreading factors in the normal noses and, interestingly enough, there was an increase in the spreading factor in the patients with colds at that time.

Dr. Kelemen's slides are most interesting and suggest the possibility of applying some of these histochemical staining techniques to the study of tonsil material.

VOCAL REST IN LARYNGEAL DISEASE.

MERVIN C. MYERSON, M.D.

Vocal rest must be intelligently applied and varies with the pathology in each case. It is of greatest value in acute cases where inflammation and edema predominate, and less useful in chronic cases characterized by fibrosis and irreversible changes; therefore, it is of no value in the treatment of vocal nodules or in the chronic stages of contact ulcer. It is useful in the preoperative days before removal of tumors and should not be prolonged postoperatively. Delay in permitting the patient to speak in some cases may lead to psychologic trauma. Within a very few days after surgery the voice may be used for moderate conversation, avoiding undue strain.

DISCUSSION.

Dr. Louis H. Clerf agreed in the main with Dr. Myerson's conception of the role of vocal rest in laryngeal therapy. Contact ulcers will not disappear under this plan except when they are of very recent origin. In both vocal nodules and contact ulcer, speech therapy may be of some value, in addition to surgery when indicated. Pre- and postoperative vocal rest, particularly the latter, should not be prolonged. Voice use after operation should be permitted, since it prevents the piling up of exudate and granulations and tends to a better anatomical and functional result.

Dr. C. L. Jackson favored moderate rest of the voice in the conditions mentioned by Dr. Myerson, but cautions the patient not to attempt talking against noises such as in traffic or busy offices. In the treatment of contact ulcer he believes there is a time and place for cautious use of the voice, but also it is important that the patient have the benefit of guidance under a speech therapist. Like Dr. Clerf, Dr. Jackson encourages patients who have undergone partial laryngectomy to begin using the voice as soon as it can be done without discomfort.

Dr. Hans Von Leden said that electronic synchrostrobic examinations with high speed photography can furnish much valuable information about the action of the vocal cords under varying conditions. On the basis of such observations he felt impelled to challenge Dr. Myerson's statement that certain lesions disappear in 24 hours. To the naked eye they may appear to shrink, but "one must consider the effect of the Bernoulli phenomenon on the lesions of the vocal cords before one draws any clinical conclusions."

Dr. Paul J. Moses pointed out that voice rest is often advised in the expectation of curing a disorder, but frequently fails because of an underlying psychological problem which is the chief cause. Voice rest will not cure a vocal disorder that is due to emotional causes. It is, therefore, important in many cases that a psychiatric evaluation be obtained before any type of therapy is proposed.

Dr. Myerson closed the discussion with the following comments: Bi-

opsies are usually not necessary in contact ulcers, since it is known that carcinoma rarely occurs on the medial aspect of the arytenoid cartilage. As for raising the voice in the presence of noise, mentioned by Dr. Jackson, this can be avoided by using ear plugs as advised by Mr. Cantor. Since the electronic synchrostroboscope is not available universally, the laryngologist must depend on his clinical observations, and he personally can attest to a number of edematous lesions which have disappeared within 24 hours and with return of perfect function.

Dr. Moses' remarks are well taken and bring up the point as to what constitutes a qualified voice therapist. Many who claim this distinction have been found to be woefully deficient. Psychotherapy may well be the answer in many cases, but there are some patients of the exhibitionist type, such as a night club singer, upon whom he had operated to remove some vocal nodules, who refused to undergo proper voice therapy and with the recurrence of the nodules, blamed the surgeon.

PANEL DISCUSSION:

REHABILITATION OF THE POST-LARYNGECTOMIZED PATIENT.

JOHN J. CONLEY, M.D., *Moderator.*

Rehabilitation of the Post-Laryngectomized Patient—
Charles M. Norris, M.D.

Vocal Therapist: Place and Contribution to the Rehabilitation Program ..... Paul J. Moses, M.D.

Rehabilitation of the Post-Laryngectomized Patient—
F. Johnson Putney, M.D.

Psychological Factors Determining the Success or Failure of the Rehabilitation Program of Laryngectomized Patients—
Bernard Stoll, M.D.

Discussion of Some Technical Aspects of Speech Aids for Post-Laryngectomized Patients ..... Harold L. Barney, M.D.

A New Surgical Technique for the Vocal Rehabilitation of the Laryngectomized Patient ..... John J. Conley, M.D.; Felix DeAmesti, M.D.,* and Max K. Pierce, M.D.*

*By invitation.

John J. Conley, M.D., Moderator, introduced the members of the panel who were to discuss various aspects of the problems of rehabilitating the laryngectomized patient. These were to include surgical aspects, electrical equipment for voice production and speech therapy. Some of these aspects have to some degree been overlooked in the past, and although some progress has been achieved, further study may prove fruitful in resolving the problems which confront these patients.

Dr. Charles M. Norris lists the deformities and disabilities likely to be encountered following extensive laryngeal and accompanying pharyngeal and neck resection. These are considered in two groups: first, are those resulting inevitably from the surgery itself, such as permanent tracheostomy and loss of sensation due to section of branches of the cervical plexus and of function of the trapezius from section of the spinal accessory.

The second group comprises deformities which may or may not be avoided, depending upon the technique. These include stenosis of the stoma, stenosis of the hypopharynx, and paralysis of the mandibular, lingual or hypoglossal nerve; also the effects of sectioning the jugular vein.

Dr. Conley commented on the clear orientation of the operated area, the relative sizes of the wound, the demands on the local tissues and the resultant deformities. This demonstration should be valuable in assessing the surgical damage inherent in various procedures.

Dr. Paul J. Moses discussed the emotional status of the patient prior to a laryngectomy and its influence on the postoperative rehabilitation. Restoring the ability to produce audible speech fails to compensate for the inability to transmit the nuances of feeling which no form of esophageal speech can duplicate. It is, therefore, important that the speech therapist be properly trained in the field of psychology and psychiatry in order to obtain the full background of the patient's personality and to be able to adjust him properly to the altered status of voice production. Placing him under the guidance of a laryngectomized patient who has mastered

the technique of esophageal speech may fail unless the latter is qualified to understand and cope with a neurotic or psychiatric patient. It is also important that the surgeon keep in close contact with the patient during the postoperative period while under tuition of the speech therapist, since it is he who is responsible for having taken away the speech, and who must display the keenest interest in seeing that it is restored.

Dr. Conley, hearing this paper for the first time, found it stimulating, provocative and humanistic. The symbolism he attached to the "Adam's apple" as an attribute of virilism in the male may well explain the differing attitudes of the male and female when anticipating removal of the larynx. The high artistic and esthetic quality of Dr. Moses' presentation should be fully appreciated by all who are interested in the subject.

Dr. F. Johnson Putney, reviewing the postoperative records of 440 patients subjected to a laryngectomy at the Jefferson Hospital, found that 38 per cent failed to develop a useful voice. The percentage of failures was higher in the female patients than the male, due to psychologic factors. The various techniques employed seemed to have but little influence on the ability to develop a voice, even when extensive removal of pharyngeal tissues, including the cricopharyngeus, was necessary; however, it was found that disturbance in the range of activity of the tongue and muscles of the floor of the mouth interfered with the ability to produce a voice as well as with the act of swallowing.

It would appear, therefore, from the analysis of this group of patients, that failure to develop a voice could not be attributed to extent of the surgery or the amount of tissue removed, with the exception of the item just mentioned.

Dr. Conley called attention to figures presented by Dr. Putney, where only 5.7 per cent of 440 patients elected to use an artificial larynx. Comparing this with 38 per cent of the cases that failed to become rehabilitated vocally, this is pretty much in line with the figures obtained at the National School for Speech Disorders in New York. It is interesting to note that no matter how much neck tissue is removed, rehabilitation is possible as long as you reconstitute the pharyn-

geal tube and preserve the muscles of the floor of the mouth and tongue.

Dr. Bernard Stoll, in attempting to evaluate the patient's attitude toward rehabilitation, enumerated the fears that beset most patients prior and subsequent to operation. The degree of anxiety varies with the temperament of the patient, his vocation, position in society and interpersonal relationship. Preoperative counselling by the physician will remove many of these fears and the presence of an intelligent, psychologically astute person, who has undergone a laryngectomy and has acquired a good esophageal speech is very helpful. Instruction within a group of laryngectomy patients lends psychologic support through the competitive element.

Necessity and willingness to learn are most essential, and as a rule, it has been found that the extrovert type of individual adapts himself to the new regimen better than the introvert. It is important during the periods of instruction to avoid the use of the word "belch" because of its disagreeable connotations.

Psychologic conditioning whereby the patient acquires confidence in the ready acceptance by the public of his newly acquired speech is most helpful in instilling the necessary confidence.

Dr. Conley stated that Dr. Stoll's paper illustrates very well the necessity for adaptation on the part of the patient in order to master the technique successfully. One can regard the patient as standing on a ladder; you either push him up into an area of greater success, if he has the adaptive capacity and necessary motivating principles, plus the support of proper schooling, or he will slip backward into failure to achieve adequate rehabilitation. If the speaking phenomenon can be made technically easier the stratum is lowered thereby putting it within reach of the patient's adaptive capacity.

Dr. Conley apologized for the absence of the film which was scheduled to be shown, due to an error on the part of the Phillips Company, who sent a film of the palate instead of the esophagus.

Mr. Harold L. Barney, of the Bell Telephone Laboratories, analyzed the problem of constructing an artificial larynx that will meet certain mechanical acoustic and commercial requirements. Improvements have been achieved with the introduction of transistors and miniature batteries; however, the ideal has not yet been attained insofar as being able to produce speech patterns which will more closely simulate the normal. In order to obtain the full advantage of tongue, lip and palate movements, as well as the resonating chambers above, it would be necessary to introduce an air column as low down in the pharynx as possible. If this could be achieved through an artificial opening in the neck, it would be ideal; but there are certain hygienic and cosmetic considerations, which are objectionable.

The author showed graphs which demonstrated the sound spectograms for certain vowels and consonants with the tube at different locations as compared with the normal.

It is anticipated that the Western Electric Model 2 device, improved with proper acoustic and electronic circuit design, should provide sufficient drive when applied to the outside of the throat to produce adequate intelligibility which will result in more natural sounding speech.

Dr. Conley and associates describe a new technical procedure whereby air can be conducted from the trachea to the esophagus for the production of controlled sound. It is accomplished by the construction of a mucosal-lined tube derived from the esophageal mucosa supported by one of the neck muscles and so directed as to be closed during the passage of food. The operation was performed on 11 patients, eight as primary procedures following the laryngectomy, and three as secondary procedures. Of the eight primary, three were technical failures (two of stenosis and one through fistula formation). The stenosis may have been due to removal of the catheter stent too soon. The fistula formation was in a patient who had had irradiation prior to laryngectomy.

In the successful cases the patients were able to speak with the first effort, and the quality of the voice was that of

pharyngeal or esophageal speech but with better air control and supply and greater ease.

DISCUSSION.

Dr. Julius McCall called attention to his paper on "Preliminary Voice Training for Laryngectomy" of 18 years ago, which set in motion the development of what was termed "The Lost Chord Club." It is his contention that training for the esophageal voice should begin before and not after surgery; also he disagreed with Drs. Moses and Stoll, who deny that the expulsion of air is not a burp or a belch. He could recall only two patients who were able to belch after laryngectomy who failed to develop a good esophageal speech. He agreed with Dr. Putney that the amount of tissue removed had little to do with the subsequent development of the speech.

Dr. Joseph H. Ogura had little to add, expressing his agreement with everything that had been said.

Dr. McNaught echoed the same sentiments.

Dr. Louis H. Clerf felt that while the opinions expressed were in many respects admirable, he could not agree with everything, since some of them were diametrically opposed. It is generally agreed that the problem is one from which the surgeon cannot divorce himself. It is he who must take the initiative in getting the patient started, since it is he in whom the patient has the greatest confidence. He agreed with Dr. McCall to the extent that whether you call it belching or burping, you have to get air into the lower pharynx. Where the dividing line is located is difficult to say. He does not have the patient deliberately swallow but encourages him to relax during inspiration so that air may accumulate in the lower passages. He himself has been able to relax his cricopharyngeus sufficiently to fill the stomach with air.

Dr. Paul H. Holinger agreed with Dr. Putney that the type of operation has little to do with the subsequent development of a speech pattern. He believed that the most important factors are the motivation by the patient and intelligent co-operation of therapist and surgeon. Often it is a question of persisting too long in efforts to produce esophageal speech in some cases, to the point of frustration when such individuals can more readily be made to accept an artificial larynx. With improved models of prothesis this medium may become more acceptable. As to preoperative training, he disagreed with Dr. McCall because it is so often an individual problem. In some cases it only adds to the burden on the patient, who has many other things to attend to before undergoing surgery. Rehabilitation and inspiration to learn can begin before the patient leaves the hospital through association with others who have acquired speech and instruction by the therapist.

Dr. Conley agreed with Dr. Holinger that one of the most important psychological points is the compulsion of the patient to speak. It may be a good idea to give the patient a speaking apparatus at the outset as a means of encouraging adaptation.

Dr. Walter H. Hoover could not entirely agree that the type of operative procedure played no role in subsequent speech development. Certainly a flexible pharynx will adapt itself to voice production better than one which is hampered by deep neck scars.

Dr. Conley closed the discussion by stating that the purpose of the panel was not so much for medification as for a stimulus to all laryngologists and allied specialists to apply themselves toward the development of new

techniques which may further the advancement of knowledge in this most important field.

THE CHANGING YEARS: THEIR IMPACT UPON THE MANAGEMENT OF PARANASAL SINUS DISEASE.

FREDERICK T. HILL, M.D.

Dr. Hill reviewed the changes that have taken place during the past 40 years in the management of sinus disease, showing how increasing knowledge of the physiology of the nose and sinuses and a better understanding of constitutional and environmental factors has led to a saner and safer attitude. He mentioned the excellent research and contributions of many members of this association which were responsible for the advances we have witnessed. He discussed the impact of allergy, endocrines and other constitutional factors as they were developed within and without our specialty, whose influence on the course and development of sinus conditions was studied by our colleagues, resulting in a more intelligent understanding of the pathogenic processes. Surgical procedures have as a result tended more and more to conservatism, as demonstrated in his analysis of the treatment of frontal, ethmoid and antrum disease. Comparing the widespread and often indiscriminate surgery of the sinuses formerly practiced on fallacious indications, with the modern conception of the sinuses as part of a total organism, it is easy to see why we are doing less surgery and obtaining better results under a comprehensive regimen which takes into account all of the contributing factors.

DISCUSSION.

Dr. Samuel Salinger confessed to an emotional reaction to Dr. Hill's presentation which was primarily a response to the realization that he was older than he had thought and, secondarily, to an amazing change in perspective.

Recalling, for instance, a meeting some years ago at which a colleague reported having done 300 intranasal frontal operations with a rasp, and with only one fatality, he is now shocked to think that at the time he was only impressed by the great skill of the surgeon without having given any thought to the question of why these operations were done.

To comment on the numerous items so ably assembled by Dr. Hill would be superfluous, but one or two personal observations are submitted. One should always be suspicious of any unilateral clouding of a sinus that is more than transitory, and should never be guilty of overlooking the possibility of a malignancy, which is so difficult to diagnose in the early stage. It is for this reason that he is a firm believer in the value of laminagraphs and X-rays with contrast media in every case that fails to yield promptly to conservative treatment.

Another conclusion to which he has been forced is that the only way to insure against recurrence after frontal sinus surgery is to obliterate the cavity. He was impressed with the work of Bergara, who uses abdominal fat to fill the sinus, and has presented evidence of subsequent development of fibro-osteoid tissue completely filling the space. In two recent cases, Salinger has used Gelfoam instead, and in following the cases with X-rays for several months, has been able to observe a gradual obliteration of all bony landmarks. This may or may not mean a permanent filling, but only time will tell.

Dr. Francis L. Weille believed that the role of allergy has been overemphasized. Many people believe that the allergist can cure recurring polyposis with anti-allergic therapy. He recalled a report by Dr. Schenck and Dr. Kern on a series of 700 cases, a third of which had polypi, in which only four were cured by anti-allergic therapy. He would like an expression from Dr. Hill on this point.

Dr. Hill closed the discussion by stating first, that he agreed with Dr. Weille as to over-emphasis on the allergic factor, although he had seen a number of cases in which this cannot be denied. Yet he doubts that polypi will disappear under allergic therapy except under the most unusual circumstances.

The subject of malignancies as well as complications was not presented, although both are included in the full paper to be published. As for Dr. Salinger's opening remark regarding the passing of time, he could say only that one thing worse than growing old is not having a chance to do so!

SURGERY TO THE NASAL LOBULE.

HENRY L. WILLIAMS, M.D.

Dr. Williams described in detail the anatomy of the nasal structure with special emphasis on the relationship of the septum to the lateral and alar cartilages. Variations in the nasal apertures are responsible for varying effects on the degree of resistance to the inspired air which produce symptoms of hyper- or hypoventilation. He pointed out that in most patients it is impossible to demonstrate the physiologic effects of these variations, and that from a practical point of view operations are indicated for the relief of subjective

symptoms. He described the symptoms caused by nostrils that are too narrow, deformities of the lobule, deviations of the lower portion of the septal cartilage, variations in the size and placement of the lateral cartilages and nasolabial angles.

The procedures for correcting these manifold conditions involve a combination of techniques which may embrace the septum, upper lateral cartilages and the lobule. The septum is dealt with through a modified resection with replacement of excised cartilage, and the lateral and lobular cartilage resected in part or cross-hatched as indicated. These techniques were given along with appropriate illustrations. Good functional results can be obtained only through careful study of the individual case, applying only those remedial measures which are strictly indicated.

DISCUSSION.

Dr. G. Edward Tremble described the anatomic differences between the nares of the Caucasian as compared with the Negro and Filipino, which account for differences in the direction of the air flow within the nasal passages. These are to be taken into account when surgery is to be undertaken which involves changes in the contour of the nares and vestibule, so that the normal pattern of air flow is not to be altered. The shape of the nares must conform to the normal Caucasian, when operating on a white individual, and the vestibule must retain the normal valve of Mink so that the air current is properly directed.

Frequently after a properly performed submucous resection, nasal blockage will be complained of, which can easily be corrected by a simple procedure on the lobule.

Dr. Samuel Salinger felt that, since Dr. Williams had introduced the subject of the septum in his consideration of deformities about the lobule, he would like to comment on that aspect of the problem. He has long been an advocate of a conservative type of operation in which the deformity is corrected with removal of a minimum of cartilage and bone. Others have had the same idea, and a variety of procedures have been described by Stevenson, Dingman, Becker and Maliniak. In all these techniques the Metzenbaum procedure has been more or less modified, the objective being the straightening of bends, curves and cartilage. The point is that no single technique is applicable to all cases, and that success depends on the ingenuity and technical skill of the individual operator.

Dr. Irving Goldman called attention to the varying shapes of the nares to be found in different races and the question as to how much influence they exert on the respiratory function. Changing the shape of the lobule may be applicable in one type and disastrous in another. In the combined septum rhinoplasty with surgery of the lobule, he is convinced that the causative factor is most generally to be found in the septum, and he agrees with Dr. Salinger that conservative procedures will yield the best results.

Dr. Juergen Tonndorf disagreed with Dr. Tremble in the statement that there is a substantial difference between the currents of inspired and expired air. Experiment of older authors did make this claim, but it was found that the difference was due to the use of too heavy material. It was disproven 20 years ago in Dr. Proetz's experiments. He also may have misunderstood Dr. Tremble as saying the current slows down as it goes through the vestibule. On the contrary, when a current of air passes through a narrow opening, its velocity must increase. The third point refers to the eddy motion of the air which through the nose is more laminary and unstable. If you calculate the Reynolds' number which indicates whether the motion will be laminary or eddying, it develops that the Reynolds number for the nose is about 1,000 in eddying. It starts at 1,100 or 1,200. This means that you are just short of eddying, and if surgery does anything to speed up the flow of air you will produce an eddying current.

Dr. Wilson stated that we are led to believe that the Caucasian nose is narrower than the Negroid type because of living in colder and drier climates. Could Dr. Williams offer any explanation of the shape of the Eskimo's nose?

Dr. Williams closed the discussion by first answering Dr. Wilson's query to the effect that not being privy to the designs of the Lord, he was unable to offer any explanation, nor did he believe the anthropologists could.

As to the remarks of Drs. Salinger and Goldman, the technique he has described here offers great flexibility and permits surgery on the lobule at the same time. He agrees that there is no set technique.

The question as to whether the various types of noses have to do with varieties of obstruction is beyond the point. Patients come to the surgeon because of obstruction, and in many instances the submucous resection is inadequate, and better results can be obtained by additional surgery on the lobule.

What the mechanism of obstruction from lobular deformities is, he would leave to mathematicians such as Dr. Tonndorf, but the fact remains that patients are relieved of their complaint when the deformities are properly corrected.

CARCINOMA IN SITU OF THE LARYNX: A TEN-YEAR STUDY OF ITS HISTOPATHOLOGICAL CLASSIFICATION, PROGNOSIS AND TREATMENT.

ALDEN H. MILLER, M.D.,
and
H. RUSSELL FISHER, M.D.

Drs. Miller and Fisher, analyzing a series of 48 patients with carcinoma *in situ* of the larynx, observed during a ten-

year period, certain data pertaining to classification, local characterists, invasive potential and results of therapy. Of the three histologic types encountered, basal cell, squamous cell and Bowmanoid, the most common was the squamous cell, which appeared to be associated with leukoplakia. Ten patients developed invasive carcinoma, most of them originating from the squamous type. Treatment by stripping, laryngofissure or X-rays was individualized on the basis of extent of the lesion, original diagnosis and development of recurrence. Laryngofissure was successful for the small lesions. More extensive lesions, especially the bilateral, received X-ray therapy, which obviated the need for laryngectomy in 17 of 23 patients.

There was only one death following laryngectomy with subsequent invasion of the lymphatics and a radical neck dissection.

DISCUSSION.

Dr. Francis E. LeJeune brought out the point that the clinical picture of carcinoma *in situ* was not characteristic and that its differentiation from invasive carcinoma could be determined only by the pathologist. The question as to whether the lesion has penetrated the basal membrane can be resolved only through serial sections, and since it is impractical to examine all the sections in a given specimen it is possible that some invasive cases may escape detection and thus account for recurrences.

He has found carcinoma *in situ* ideal for removal by suspension laryngoscopy with wide excision, followed by electric coagulation of the base. Dr. LeJeune inquired of Dr. Fisher as to why he found it necessary to use the words "without invasion" in referring to these growths, since penetration of this barrier changes the picture, and one is now dealing with an invasive carcinoma and not a carcinoma *in situ*. He would also like Dr. Miller to explain why he was impelled to do laryngofissure in some of these cases.

As to statistics, he has not had an opportunity to review his own, but is under the impression that he had seen very few recurrences.

Dr. Eugene S. Hopp suggested a possible explanation for invasion which might reconcile the points of view of Drs. LeJeune and Fisher, namely, that invasion and even metastasis depends on the integrity of the ground substance. Some excellent work has been done showing that metastases develop where depolymerization of ground substance has taken place. It would be interesting and profitable to do histochemical stains on these carcinomas with the idea of ascertaining whether those which subsequently developed extension or invasion showed this depolymerization in the sections and whether those which did not develop showed intact ground substance.

Dr. Julius McCall would view carcinoma *in situ* as an unpredictable lesion. As stated by Dr. LeJeune, much depends on the area from which a biopsy is taken, since a distance of a few millimeters may produce an entirely different picture. This was illustrated in pictures shown by Dr.

McCall of a case where one section showed intact basement membrane, whereas another showed a break through.

Dr. Miller closed the clinical side of the discussion by stating that he had attempted to make the distinction between the strictly intraepithelial growths and those showing invasion, the latter being excluded from the series, if recognized.

Regarding the potentially malignant character of these lesions, Dr. Miller agreed with Dr. LeJeune that every case is potentially invasive, although in many cases the invasive character is not manifested until years later. Initially, a clinical diagnosis cannot be made from the appearance of the lesion, many of them being leukoplakia cases on the surface.

Dr. Fisher explained his terminology "without invasive carcinoma" to emphasize that all parts of the tissue had been examined. He may perhaps have been too redundant for this audience, but has so often been asked "was there not invasion in some other part" that as a result it has been his habit to add the words "without invasive features."

The point brought up by Dr. Hopp is an important one, and it must be conceded that the character of the ground substance has much to do with the chance of invasion. He has made studies in a few cases but not systematically. Alterations in the ground substance have been observed in simple keratosis, chronic laryngitis, as well as carcinoma *in situ* without, however, revealing any specific change characteristic of carcinoma *in situ*. Dr. McCall's case brings to mind the studies on carcinoma *in situ* of the cervix in which a potential to invasion has been more or less fixed. By comparison the cases involving the larynx occupy a place midway between the peak age of cervix lesions and keratosis, being estimated at about eight years. Dr. McCall's slides demonstrate the difficulty that arises when only one section is examined. One slide appeared to be simple metaplasia, another showed carcinoma *in situ* at one spot, and another showed it with invasion.

BRONCHOSCOPIC FINDINGS IN TUBERCULOUS CHILDREN (A FIFTEEN YEAR STUDY).*

Dr. Whaley described the results of their bronchoscopic examinations of 144 children with bronchial tuberculosis. Many of these had bronchograms as well, and a total of 273 examinations was made. They give the details of the procedure, which is carried out under general anesthesia in a properly ventilated room with shock and explosion-proof apparatus.

Primary bronchial tuberculosis was found in a limited number of cases, the result of direct infection of the mucosa,

*Due to the untimely death of Dr. Wishart, this paper was presented by Dr. Whaley.

which revealed redness and swelling over a limited area. Most commonly the upper lobe bronchi and the lingula were affected.

Secondary tuberculous bronchitis was found more frequently and often called for emergency treatment. Compression of a bronchus due to pressure of enlarged glands was a common finding, and frequently there was an accumulation of caseous material and granulations, due to rupture of a caseous gland into the lumen. These called for bronchoscopic removal. Other findings were bronchiectatic lesions of the "flagellate" type.

Following unsuccessful trials with streptomycin, para-amino-salicylic acid (PAS) and isotonic acid hydrozide (INH) proved more successful. Repeated bronchoscopic aspiration with removal of granulations was helpful in many cases. In a few it was necessary to resort to lobectomy and occasionally to pneumonectomy.

Numerous pictures showing bronchograms illuminated the presentation.

DISCUSSION.

Dr. Mervin C. Myerson found that the age group below two years is the worst from the standpoint of prognosis. In the group between the age of 4 and 14 about 15 to 20 per cent present the type of lesion seen in adults. In the infant and young child the glands cause the most trouble, often to the point of obstructing the bronchi. These glands may develop in two directions; one, erosion into a bronchus; the other, by lymphatic extension to the bronchial mucosa. This may be either a submucous infiltration or an open ulceration. Dr. Myerson showed slides depicting lesions in the parenchyma and showing the manner of extension to the bronchi. Generally speaking, one may safely attempt to remove a granuloma, but if the lesion is caseous, surgical trauma might precipitate a miliary spread to other parts of the body; also he would not recommend dilating a bronchial stenosis because of a hematogenous spread.

Dr. J. P. Atkins has found that it is safe to remove endobronchial caseation debris without danger of dissemination, probably due to the effectiveness of the antibiotics, and the improved ventilation is certainly beneficial.

Dr. Whaley, in closing, agreed with Dr. Myerson that many cases do not respond to endobronchial therapy and have to submit to surgery. As for the caseous lesions, he agreed that cautious removal of the debris is desirable while, on the other hand, as Dr. Myerson pointed out, dilatation is risky.

THE CLINICAL SIGNIFICANCE OF THE ANATOMICAL ARRANGEMENT OF THE PARANASAL SINUSES.

FRED W. DIXON, M.D.

A study of 200 wet specimens by Dr. Dixon yielded a number of observations which have proven of value in surgery of these areas. These include the accessibility of the middle meatus for irrigation of the antrum, the variations in size and disposition of the ethmoid cells, the variations in size and relative positions of the two frontal sinuses and the extreme variability of the sphenoid sinuses. Dr. Dixon pointed out the value of closely observing the fovea ethmoidalis, which is an excellent landmark when performing surgery on the ethmoids via the intranasal approach. Preserving as much as possible of its mucosa, plus that which covers the superior and supreme turbinals, and as much as possible of the middle turbinate will prove valuable in avoiding complications.

Recurrence of polypi can be expected if the surgery is incomplete and in allergic individuals. A resume of 200 intranasal ethmoidectomies showed 25 per cent with recurrences, mostly in allergic cases and in individuals who rejected complete removal.

DISCUSSION.

Dr. Walter P. Work stressed the points brought out by Dr. Dixon relating to the variations of the frontal sinuses. In narrow frontal sinuses it is extremely difficult to preserve a functional frontal duct. The chances are better in cases where the anterior dimension of the sinus is greater. Surgical treatment of the frontal sinuses must of necessity include associated surgery of at least a portion of the ethmoid labyrinth, and here a knowledge of the disposition of the cells is of great value.

Dr. Work has found that serious complications were most frequently encountered in the allergic cases, and inquired of Dr. Dixon whether this had been his experience also.

Dr. Barry J. Anson, as an anatomist, expressed his appreciation in having been able to hear two papers dealing with the morphology of the sinuses. At the onset of the antibiotic era he had been led to believe that the mention of sinusitis would be an anachronistic act. Now that it appears that sinusitis still exists despite antibiotics, he fears curricular encroachment by clinical courses on the time formerly available for preclinical courses. In his department he has already lost 30 per cent of previously allotted time. Since it is apparent that hours must be recaptured for teaching anatomy the pressure and influence must come from the clinicians. Meanwhile postgraduate lectures of the type pre-

sented here are refreshing and helpful additions to make up for deficiencies in the undergraduate instruction.

Dr. W. Likely Simpson described his approach to the frontal sinus through the floor with complete removal of all mucosa and all septa between the frontal and the ethmoids. Visualization of all parts of the large sinus is accomplished with the use of small mirrors. No irrigation is practical, and only a small gauze is left under the middle turbinate, which is removed on the third day. No further drainage is employed, since there is no nasofrontal duct left, the fronto-ethmoid cavity being all in one.

Dr. Francis W. Davison complimented Dr. Dixon on his paper and called attention to a previous presentation of his which was given at the meeting of the American Laryngological Association, which he considers a classic. He inquired as to when and where this was to be published.

Dr. Kinsey M. Simonton called attention to Dr. Dixon's reference to removal of the middle turbinate which has been invaded by a cell. He has found it practicable to remove only one wall, thus leaving the other for physiologic functioning.

Dr. Dixon closed the discussion by first replying to Dr. Simonton. It is his practice to leave as much of the turbinal structure as possible on the side facing the septum. This has proven helpful in preserving the olfactory sense.

The article mentioned by Dr. Davison will appear in the *Annals*. He agrees that the operation for removal of polypi should be done in the hospital, where a more thorough job can be accomplished, and also agrees with Dr. Simpson that thorough removal of all the tissue will yield the best results.

Dr. Anson's point is well taken. We need more teaching of anatomy and pathology at the undergraduate level.

About swimming, like all rhinologists he feels that it should be interdicted for all patients having chronic sinus trouble.

As to indications for the operation, it should be required in all cases where ventilation and drainage has failed, and where irreversible changes have taken place.

ORBITAL APEX SYNDROME.

AUSTIN A. SMITH, M.D.

Dr. Smith described the oribinal apex syndrome as the clinical manifestation of a lesion which affects the nerves and vessels that pass through the optic foramen and sphenoid fissure. The chief symptoms are severe temporoparietal pain, impairment or loss of vision, ptosis and ophthalmoplegia. It may be due to infection, neoplasm or trauma, and can originate either in the retro-orbital region or in the posterior sinuses.

Five cases are cited: one being due to a severe upper respiratory infection, one to a posterior sinus infection, a third to a carcinoma originating in the ethmosphenoid area. The fourth was a complicated case which, after careful study and radical surgery, proved to be an extensive involvement of all the sinuses in a gangrenous destructive process with necrosis apparently due to endarteritis and thrombophlebitis. The last case was due to trauma resulting from a fall from a ladder.

The clinical history of these cases affords an interesting study in diagnosis and therapy.

DISCUSSION.

Dr. Oliver E. Van Alyea pointed out some of the anatomic features of the orbital apex, explaining the symptomatology.

The complete syndrome as described by Dr. Smith is, fortunately, quite rare; but an uncomplete syndrome may be more common. Two cases are cited: one due to an aneurysm of the internal carotid artery; the other, to a retrobulbar cyst. This latter patient, a girl of 13, after drainage of the cyst still persisted in having severe headaches and a mild ptosis. Surgery on the affected ethmoid was advised, but was rejected by the parents on religious grounds. Dr. Van Alyea asked Dr. Smith how he would proceed in such a case.

Dr. Smith replied to Dr. Van Alyea's question by calling attention to the necessity of having the cooperation of the neurologist, ophthalmologist, neurosurgeon and X-ray man. Too often, however, the case goes from internist to ophthalmologist and neurologist and X-ray man without consultation with the rhinologist, because the possibility of a sinus involvement is overlooked. This may be due to the fact that antibiotics have often been considered as having eliminated sinus disease. This is indeed a grievous error. In the particular case mentioned by Dr. Van Alyea, every effort should be made to at least explore the ethmoids cautiously.

PHYSIOLOGY OF THE LARYNX UNDER DAILY STRESS.

PAUL G. MOORE, M.D.,*
and
HANS VON LEDEN, M.D.*

Drs. Moore and Von Leden demonstrated the action of the vocal cords in a slow motion film which reveals their responses

*By invitation.

under daily stress. Numerous subjects were checked and rechecked to insure the accuracy of their interpretations. Two new ideas ensued following a study of the film which seemed to alter previous concepts of the physiology of the larynx.

1. The old concept that the cords open faster than they close is not true. Opening and closing phases are related to the intensity of the voice.

2. The larynx is capable of biphasic movements, which to date had been considered impossible.

It is hoped that these studies will lead to a better understanding of the frequently observed disparity between the degree of hoarseness and the objective findings in the larynx, and point the way toward a more rational treatment of early larynx disorders.

DISCUSSION.

Dr. John A. Murtagh expressed his admiration for the film just shown, which he appreciated all the more because of some experience with a highspeed Fairchild industrial motion analysis camera which he had been using in an effort to evaluate the basic physiology of the larynx in animals. He confessed that his film could not compare with the one just shown. This type of work should be encouraged, because so much can be learned which was previously unexplained.

Dr. Von Leden stated that it is at first difficult to accustom oneself to viewing these pictures, but that after seeing them frequently, many new factors can be seen and understood.

THE MANAGEMENT OF CHRONIC LARYNGEAL STENOSIS.

PAUL H. HOLINGER, M.D.,
and
KENNETH C. JOHNSTON, M.D.*

Drs. Holinger and Johnston reviewed their experiences in 163 cases of chronic laryngeal stenosis over a period of ten years. Sixty-one of these were congenital in origin, 43 were inflammatory and 57 were traumatic. Each of these types

*By invitation.

is described and illustrated by a typical case. The authors have noted recently a decline in the percentage of cases due to inflammatory processes, and an increase in the number of post-traumatic lesions. They point out the importance of early attention to fractures of the larynx in the prevention of subsequent stenosis from scarring and maladjusted cartilage. Tracheotomies were performed in 138 of the 163 cases and dilatations were carried out in 123.

They also call attention to the value of voice therapy in the development of proper phonation and respiratory control.

DISCUSSION.

Dr. Daniel C. Baker, Jr., has found that long-continued bougienage in children is frequently disappointing. In adults it is difficult because of the pain and discomfort which cannot always be avoided, even with local anesthesia or nerve block. Rubber core molds as suggested by Jackson are irritating and cause considerable laryngeal reaction. McNaught's keel is excellent for web stenoses, especially the acquired type. This is frequently the result of using the cautery, and he is in agreement with Dr. Holinger, who advises against it. The stent graft, as described by Figi, has been most useful when followed by the acrylic mold.

Dr. Holinger's experience with traffic injuries is most valuable, and his suggestions for their management are extremely important.

Indwelling catheters for feeding in some tracheotomy cases will often delay decannulization because of reaction in the larynx due to the tube.

Four cases of necrosis of the thyroid cartilage with resulting draining fistulae over a period of years were cured only after surgical removal of the diseased cartilage.

Dr. Holinger's presentation may well serve as a proper guide in the management of laryngeal stenosis of the chronic form.

EVIDENCE OF LARYNGEAL PARTICIPATION IN EMOTIONAL EXPRESSION: ITS RELATION TO HYSTERICAL APHONIA.

A. C. FURSTENBERG, M.D.

Experimental electrical stimulation of various cerebral areas in the monkey have demonstrated secondary motor areas which may activate laryngeal movements. These have separate and distinct pathways to the nucleus ambiguus and can carry impulses eliciting laryngeal movements even in cases of

supranuclear laryngeal paralysis. The secondary motor areas are in fields which, on stimulation, result in homolateral movements of the facial muscles, jaw and tongue. Theoretically, therefore, it should be possible to train the larynx to function in patients with supranuclear lesions which have produced bilateral laryngeal paralysis.

It was also found that some of the additional motor areas are in fields which have to do with emotional responses. This has been demonstrated in a case of hysterical aphonia. The patient, when aroused, may scream loudly and even speak audibly.

It is also probable that the additional motor areas of the larynx, like those of other types of movements, serve as centers for automatic associated movements, as illustrated by unaware whistling, humming and talking to oneself.

It is assumed on the phylogenetic basis that these experimental findings in monkeys represent a similar pattern in the human.

DISCUSSION.

Dr. Stanton Friedberg recalled some of Dr. Furstenberg's previous papers on the subject of laryngeal innervation, in which the role of supranuclear lesions in the production of laryngeal paralysis were demonstrated. His present contribution gives strong experimental evidence of secondary motor areas supplying pathways to the nuclei which can activate laryngeal movements. While Penfield and Rasmussen demonstrated laryngeal movements through stimulation of the human cortex at surgery, it remained for Dr. Furstenberg to demonstrate and record them photographically and then study the postmortem specimens of cortical areas stimulated.

The emotional connotations of hysterical aphonia as explained by Dr. Furstenberg may not be the only factors, since Jackson hinted long ago that an "ephemeral adductor paralysis may be due to sudden anemia of the anterior cerebral cortex as in syncope or fainting;" however, this has not been proven by anatomic or physiologic studies.

Dr. Furstenberg's suggestion that stimulation or inhibition of hypothalmic areas concerned with emotional expression may stem from certain definite regions of the brain, it could supply the physiologic evidence to explain hysterical aphonia.

In Memoriam

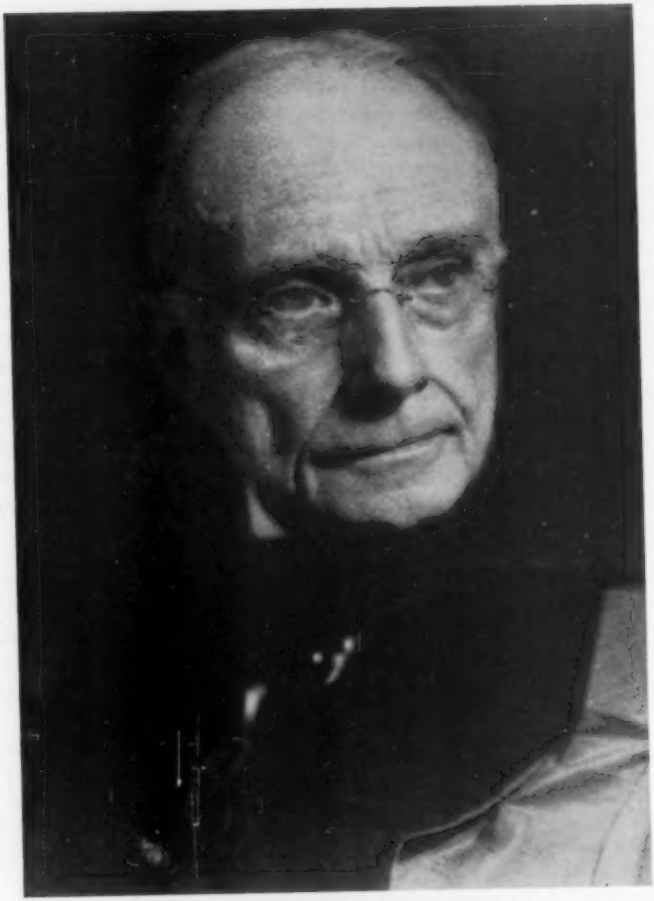
CHEVALIER JACKSON, M.D., Sc.D., LL.D., L.H.D., F.A.C.S.

1865-1958.

Like a Hick'ry cog,
In the old mill wheel;
He did his part,
As his turn came 'round

With these words as a postscript, Chevalier Jackson closed his autobiography. He considered his life's work and responsibilities in this vein and with determination, persistence and singleness of purpose fulfilled his role in life as he saw it, in spite of hardship, adversity, discouragement and even ridicule. It is gratifying to know that he lived to see his accomplishments appreciated at their full worth, and to know that many of his pioneering procedures became standard, routine techniques in both the diagnostic and therapeutic aspects of diseases of the air and food passages.

Chevalier Jackson was born in Pittsburgh, Pa., on November 4, 1865. His mother and father were natives of the State. French ancestry gave him his name, and a love of the French language, the culture and the country itself, throughout his life. His early years in Pittsburgh, in a coal mining and farming community were rough; but habits of early rising, long hours of work and a keen interest in drawing, painting and making things with his hands were developed at this formative stage. At 12 years of age he had his first experience in retrieving a foreign body—tools used in drilling for oil, lost down a 1500-foot test well. The successful solution of this mechanical problem further molded his later career; the achievement of a task previously considered "impossible" continued to stimulate him throughout his life.



Chevalier Jackson, M.D., Sc.D.,
LL.D., L.H.D., F.A.C.S.

Early schooling was most difficult, not because of schoolwork, but because of the bullying by the larger, rough, miners' boys in the country school. The study of medicine, as was customary at that time, was begun under a preceptor. In 1884, after working for a year painting glass and china to obtain funds, Jackson entered Jefferson Medical College. The medical curriculum consisted of two Winter courses of lectures and clinics from October through March. At the conclusion of the first Winter course he became a salesman of medical books. This took him to New England and gave him the opportunity to study his texts while waiting in doctors' offices; unfortunately the physicians usually claimed they were too busy to read books and sales were few. Completing the coverage of his territory in Gloucester, Mass., Jackson shipped on a Gloucester fishing schooner for the remainder of the summer at $10.00 a month, plus a share in the catch. Taking over as ship's cook improved his income. This and his earnings from another month's work in a decorating shop painting china, enabled him to return for his second year of medical school. His medical degree was conferred in 1886 when he was but 21 years of age.

Specialization in a limited field was rare at that time, but interest in the field of laryngology, stimulated by the work of J. Solis Cohen and the writings of Sir Morell Mackenzie led to a trip to England to visit Mackenzie's clinic. Returning from Europe as a specialist at the age of 22, Jackson began his work in laryngology in Pittsburgh. He demonstrated the value of tonsillectomy and adenoidectomy in children, and tried to establish a health program of throat inspection in the public school system. Although this effort was unsuccessful, the experience in dealing with government agencies was of value later in pressing legislation concerning the labeling of lye as poison.

His interest in endoscopy began in 1890 when he developed an esophagoscope with which he removed a dental plate from the esophagus of an adult, and a coin from a child's esophagus. Adoption of Einhorn's suggestion of using a light carrier on

the speculum made it a practical instrument, the basic design of which has been retained in most of the present day esophagoscopes. A vast experience in intubation and tracheotomy for diphtheria, and experience in the management of post-diphtheritic laryngeal stenosis acquired during the last decade of the Nineteenth Century, served as a background for subsequent work in bronchoscopy. Foreign body extraction proved an absorbing challenge in the years that followed. This necessitated the development of new instruments, techniques and procedures. Jackson insisted on perfecting the solution of a mechanical problem of foreign body extraction by trial, first on a manikin board, then in the cadaver and finally in the anesthetized dog. Constant research, self-training and discipline permitted him to achieve perfection, utilizing these progressive steps. Jackson stressed the principle of education of the eye and the fingers through practical experience gained by extracting foreign bodies from the air and food passages of anesthetized dogs. Physicians from every country in the world participated in the courses which he conducted in Pittsburgh, later in Philadelphia and in Paris.

In 1899 Chevalier Jackson married Alice White of Pittsburgh. She accepted and understood his devotion to the development of his special field of medicine. She encouraged him and sheltered him from what they both considered unnecessary social obligations that might take time from study or writing; she preceded him in death by only a few months.

By the turn of the Century, Jackson was receiving increasing recognition in the field of laryngology and in the new fields of bronchoscopy and esophagoscopy. In 1911 he was President of the American Laryngological, Rhinological and Otological Society, and in the following year was elected Professor of Laryngology at the University of Pittsburgh; however, a change in activity was necessitated at this time by an attack of pulmonary tuberculosis. Enforced rest was mandatory, but the time was far from lost. Characteristically, rest periods became an opportunity to write, and the first complete text on "Peroral Endoscopy and Laryngeal Surgery"

was prepared and published in 1914. This and an earlier text in 1907 were richly illustrated by Jackson, who stressed this form of teaching in lectures as well as texts. No one who ever saw him sketch with both hands while lecturing will forget the drawings or the points they illustrated. He used his line and chalk drawings, as well as oil paintings of endoscopic pathology in the texts, and they became the basic works in this new field of medicine.

Foreign body work became Chevalier Jackson's greatest interest, and his skill in the management of the difficult case and his success in safely removing a foreign body after others had failed were soon recognized; however, more than anyone else, he demonstrated the value of bronchoscopy and esophagoscopy in the diagnosis and treatment of other diseases of the chest, and the safety with which these procedures could be done in infants as well as adults. Peptic esophagitis, the upper and lower pinch-cock of the esophagus, bronchial adenoma, post-operative atelectasis and other phenomena he described were received with skepticism, but later were accepted as definite clinical entities. In 1916 Jackson was offered the Professorship of Laryngology at Jefferson Medical College and moved to Philadelphia to accept this position. Here he became recognized as the world's leading laryngologist and bronchoscopist. In 1917 he was instrumental in founding the American Bronchoscopic Society and served as its first president. He had been a Founder Member of the American College of Surgeons in 1913. In 1919 he was elected to fill the new chair of Bronchoscopy and Esophagoscopy created for him at the University of Pennsylvania Graduate School of Medicine. He later received similar appointments at Temple University and Women's Medical College. He became President of the Women's Medical College in 1935.

During these years Jackson received innumerable medical honors in this country and abroad. He traveled widely to give papers on bronchoscopy and allied subjects and visited all parts of the world to teach the principles and techniques of peroral endoscopy. He was an honorary member of medical

societies throughout Europe, North, South and Central America and all parts of the United States. In 1926 he was President of the American Laryngological Society and received the DeRoaldes Award in Laryngology. He was a recipient of the Philadelphia Bok Award, was made a Chevalier de la Legion d' Honneur (France) and Chevalier de l'Ordre de Leopold (Belgium) in 1927. He was the recipient of the Henry Bigelow Medal awarded by the Boston Surgical Society in 1928; the Cresson Medal of the Franklin Institute in 1929, the I. P. Strittmatter Award in 1932, and in 1933 received the Gold Medal of the Radiological Society of North America. The highest honor in American Medicine, the Distinguished Service Medal of the American Medical Association was conferred on him in 1940. The award of the American College of Chest Physicians, for meritious Services in Diseases of the Chest was given him in 1952.

Jackson was the first to point out that the field of peroral endoscopy had broadened to justify considering it as an "-ology" rather than an "-oscopy"; a "study of" rather than merely a "looking into." He coined the word "bronchoesophagology" to indicate this advance, and it has come into common usage. Those who stumbled over its pronunciation were gently reminded of the similar term, "gastroenterology."

One of the achievements accomplished through the dogged determination so characteristic of Dr. Jackson was the passage of the Federal Caustic Act by Congress in 1927. He effected this through personal appearances before numerous senators, congressmen and committees. He used the many children under his care at that time as a living demonstration of the need for this legislation. This law made mandatory the labeling of caustics as poisons, and required the printing of the antidote on the label. Jackson obtained great personal satisfaction from this triumph. The pen with which President Coolidge signed this bill was presented to him by the President.

Holding five chairs of Bronchoscopy and Esophagoscopy in as many separate medical schools was a unique achieve-

ment. It attested to Jackson's constant drive to teach and to broaden the field of bronchoscopy. In the separate clinics he developed individuals who carried on his work in strictest adherence to his principles. Dr. Ellen J. Patterson of Pittsburgh continued his work there when he moved to Philadelphia. Dr. Louis Clerf continued at Jefferson Medical School, maintaining the international reputation of that world famous clinic. Dr. Gabriel Tucker carried on in like manner at the Graduate School as did Dr. Emily Van Loon at the Women's Medical College.

The great modesty, sincerity and singleness of purpose of this man, who lived through almost a century of medicine can hardly be realized. He developed a specialty through keen observation, consummate skill and great perseverance. He discussed its problems and their solutions with his colleagues, but his wealth of clinical experience kept him far in the lead in any consultation. He gave his opinion when it was asked, but often with the disarming statemnet, "But of course, I have just one vote, you know." His kindness, gentleness, and courtesy pervaded all his actions, and these basic attitudes commanded the greatest respect from his patients and the colleagues who worked with him; yet his strict formality gave only a very few an opportunity to know him, except through medical discussions. Those few who had the privilege of a visit to "The Mill" where he lived in the beautiful countryside outside of Philadelphia, saw a man keenly interested in nature and humble in his appreciation of the beauty of his surroundings. He was fascinated by the mechanics of the mill wheels, the electric boat he used on the mill pond and the wood and metal tools he could use so well. Even carving a roast at dinner was a task requiring a host of intruments, all laid out before him with precision and in exact order. At Old Sunrise Mills he cherished the warmth of the family circle. He derived great pleasure, for example, working with his granddaughter preparing the drawings for one of his last papers, illustrating the types and action of grassheads as foreign bodies in the bronchi.

Dr. Jackson experienced great personal satisfaction in the establishment and subsequent development of the Chevalier Jackson Bronchoscopic Clinic of Temple University Hospital and Medical School. Here, his son, Chevalier L. Jackson, joined him in the clinical work and teaching program in bronchoesophagology and laryngeal surgery. The quiet, friendly guidance, the teaching of technical skill and medical judgment, and finally the transfer of authority from one generation to the next, was one of the ways in which the character and wisdom of this great man were most beautifully revealed. Under the son's guidance, the father's work continues.

In all medical achievements the beginning can never be defined, nor the end envisioned. Chevalier Jackson's influence in medicine will continue to be felt far beyond the borders of his country and the span of his life. Modern medicine, as well as his individual patients, pay great homage to this man who did so much more than his part "as his turn came 'round."

DIRECTORY OF OTOLARYNGOLOGIC SOCIETIES.

(Secretaries of the various societies are requested to keep this information up to date).

AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY.

President: Dr. Erling W. Hansen, 90 So. Ninth St., Minneapolis, Minn.
Executive Secretary: Dr. William L. Benedict, Mayo Clinic, Rochester, Minn.
Meeting: Palmer House, Chicago, Ill., Oct. 10-15, 1959.

AMERICAN BOARD OF OTOLARYNGOLOGY.

AMERICAN BRONCHO-ESOPHAGOLOGICAL ASSOCIATION.

President: Dr. Francis W. Davison, Geisinger Memorial Hospital, Danville, Pa.
Vice-President: Dr. George S. McReynolds, 615 N. Boulevard, Galveston, Tex.
Secretary: Dr. F. Johnson Putney, 1712 Locust St., Philadelphia 3, Pa.
Treasurer: Dr. Verling K. Hart, 106 W. 7th St., Charlotte, N. C.
Meeting: The Homestead, Hot Springs, Va., March 10-11, 1959.

AMERICAN LARYNGOLOGICAL ASSOCIATION.

President: Dr. Fred W. Dixon, Cleveland, Ohio.
Secretary: Dr. James H. Maxwell, Ann Arbor, Mich.
Treasurer: Dr. Francis E. LeJeune, New Orleans, La.
Editor, Historian, and Librarian: Dr. Edwin N. Broyles, Baltimore, Md.
Meeting: The Homestead, Hot Springs, Va., March 8-9, 1959.

AMERICAN LARYNGOLOGICAL, RHINOLOGICAL AND OTOLOGICAL SOCIETY, INC.

President: Dr. Gordon Hoople, 1100 E. Genesee St., Syracuse 10, N. Y.
President-Elect: Dr. Theo. E. Walsh, 640 So. Kingshighway, St. Louis 10, Mo.
Secretary: Dr. C. Stewart Nash, 700 Medical Arts Bldg., Rochester 7, N. Y.
Annual Meeting: The Homestead, Hot Springs, Va., March 10-11-12, 1959. (Mornings only).

Meetings of the Sections:
Eastern: Savoy Plaza, New York, N. Y., January 8-9, 1959.
Council: Savoy Plaza, New York, N. Y., January 10, 1959.
Middle: Park Plaza Hotel, St. Louis, Mo., January 12-13, 1959.
Western: The Ahwahnee Hotel, Yosemite Valley, Calif., January 17-18, 1959.
Southern: Academy of Medicine, Hotel Atlanta Biltmore, Atlanta, Ga., January 23-24, 1959.

AMERICAN MEDICAL ASSOCIATION, SECTION ON LARYNGOLOGY, OTOLOGY AND RHINOLOGY.

Chairman: Dr. Victor R. Alfaro, Washington, D. C.
Vice-Chairman: Dr. Harold F. Schuknecht, Detroit, Mich.
Secretary: Dr. Walter E. Heck, San Francisco, Calif.
Representative to Scientific Exhibit: Dr. Walter H. Maloney, Cleveland, Ohio.
Section Delegate: Dr. Gordon F. Harkness, Davenport, Ia.
Alternate Delegate: Dr. Dean M. Lierle, Iowa City, Ia.
Meeting: Atlantic City, June 8-12, 1959.

AMERICAN OTOLOGICAL SOCIETY, INC.

President: Dr. Moses Lurie, Boston, Mass.
President-Elect: Dr. R. C. Martin.
Secretary: Dr. Lawrence R. Boies, University Hospitals, Minneapolis 14, Minn.
Meeting: The Homestead, Hot Springs, Va., March 13-14, 1959.

AMERICAN OTORHINOLOGIC SOCIETY FOR THE ADVANCEMENT OF PLASTIC AND RECONSTRUCTIVE SURGERY.

President: Dr. Joseph Gilbert, 111 E. 61st St., New York, N. Y.
Vice-President: Dr. Kenneth Hinderer, 402 Medical Arts Bldg., Pittsburgh, Pa.
Secretary: Dr. Louis Joel Feit, 66 Park Ave., New York 16, N. Y.
Treasurer: Dr. Arnold L. Caron, 36 Pleasant St., Worchester, Mass.

AMERICAN RHINOLOGIC SOCIETY.

President: Dr. Russell I. Williams, 408 Hynds Bldg., Cheyenne, Wyo.
Secretary: Dr. Robert M. Hansen, 1735 No. Wheeler Ave., Portland, Ore.
Annual Clinical Session: Illinois Masonic Hospital, Chicago, Ill., October, 1958.
Annual Meeting:

AMERICAN SOCIETY OF FACIAL PLASTIC SURGERY.

President: Dr. Trent W. Smith, 327 East State St., Columbus 15, Ohio.
Vice-President: Dr. Oscar J. Becker, Chicago, Ill.
Secretary: Dr. Samuel M. Bloom, 123 East 83 St., New York 28, N. Y.
Meeting: November 12, 1958, in conjunction with the Section on Laryngology, Rhinology and Otology of the Medical Society of the County of Kings and Academy of Medicine of Brooklyn, 1313 Bedford Ave., Brooklyn, N. Y.

AMERICAN SOCIETY OF OPHTHALMOLOGIC AND OTOLARYNGOLOGIC ALLERGY.

President: Dr. Joseph W. Hampsey, Grant Bldg., Pittsburgh 19, Pa.
Secretary-Treasurer: Dr. Daniel S. DeStio, 121 S. Highland Ave., Pittsburgh 6, Pa.
Annual Meeting:

ASSOCIACAO MEDICA DO INSTITUTO PENIDO BURNIER—CAMPINAS.

President: Dr. Antonio Augusto de Almeida.
First Secretary: Dr. Alberto Galo.
Second Secretary: Dr. Alfredo Porto.
Librarian-Treasurer: Dr. L. de Souza Queiroz.
Editors for the Archives of the Society: Dr. J. Penido Burnier, Dr. Guedes de Melo Filho and Dr. Roberto Franco do Amaral.
Meetings: Twice every month, first and third Thursdays, 8:30 P.M.

ASOCIACION DE OTORRINOLARINGOLOGIA Y BRONCOESOFAGOLOGIA DE GUATEMALA.

Presidente: Dr. Julio Quevedo, 15 Calle Oriente No. 5.
First Vice-Presidente: Dr. Héctor Cruz, 3a Avenida Sur No. 72.
Second Vice-Presidente: Dr. José Luis Escamilla, 5a Calle Poniente No. 48.
Secretario-Tesorero: Dr. Horace Polanco, 13 Calle Poniente No. 9-D.

ASOCIACION DE OTO-RINO-LARINGOLOGIA DE BARCELONA, SPAIN.

Presidente: Dr. J. Abello.
Vice-Presidente: Dr. Luis Suñe Medan.
Secretario: Dr. Jorge Perellò, 319 Provenza, Barcelona.
Vice-Secretario: Dr. A. Pinart.
Vocal: Dr. J. M. Ferrando.

BALTIMORE NOSE AND THROAT SOCIETY.

Chairman: Dr. Walter E. Loch, 1039 No. Calvert St., Baltimore, Md.
Secretary-Treasurer: Dr. Theodore A. Schwartz.

BUENOS AIRES CLUB OTOLARINGOLOGICO.

Presidente: Dr. K. Segre.
Vice-Presidente: Dr. A. P. Belou.
Secretario: Dr. S. A. Aranz.
Pro-Secretario: Dr. J. M. Tato.
Tesorero: Dr. F. Games.
Pro-Tesorero: Dr. J. A. Bello.

CANADIAN OTOLARYNGOLOGICAL SOCIETY SOCIETE CANADIENNE D'OTOLARYNGOLOGIE.

President: Dr. Robert T. Hayes, 42 Cobourg St., St. John, N. B.
Secretary: Dr. Donald M. McRae, 324 Spring Garden Rd., Halifax, N. S

CENTRAL ILLINOIS SOCIETY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY.

President: Dr. G. C. Otrich, Belleville, Ill.
President-Elect: Dr. Phil R. McGrath, Peoria, Ill.
Secretary-Treasurer: Dr. Alfred G. Schultz, Jacksonville, Ill.

CHICAGO LARYNGOLOGICAL AND OTOLOGICAL SOCIETY.

President: Dr. Stanton A. Friedberg, 122 So. Michigan Ave., Chicago 3, Ill.
Vice-President: Dr. Maurice Snitman, 408 So. 5th Ave., Maywood, Ill.
Secretary-Treasurer: Dr. Fletcher Austin, 700 No. Michigan Ave., Chicago 11, Ill.
Meeting: First Monday of each month, October through May.

CHILEAN SOCIETY OF OTOLARYNGOLOGY.

President: Dr. Enrique Grünwald S.
Vice-President: Dr. Agustin Estartus.
Secretary: Dr. Marcos Chaimovich S.
Treasurer: Dr. Benjamin Kapkan K.
Director: Dr. Alberto Basterrica A.

COLORADO OTOLARYNGOLOGY SOCIETY.

President: Dr. James T. Blair, Denver, Colo.
Vice-President: Dr. James Rigg, Grand Junction, Colo.
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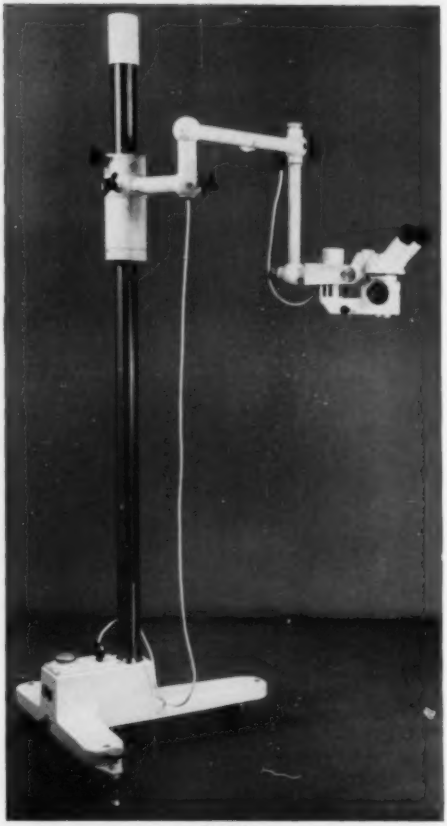

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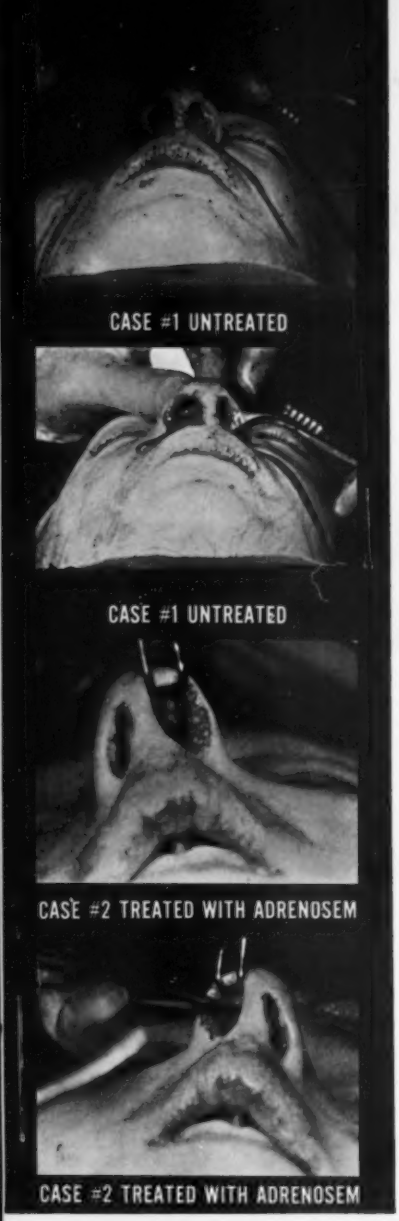

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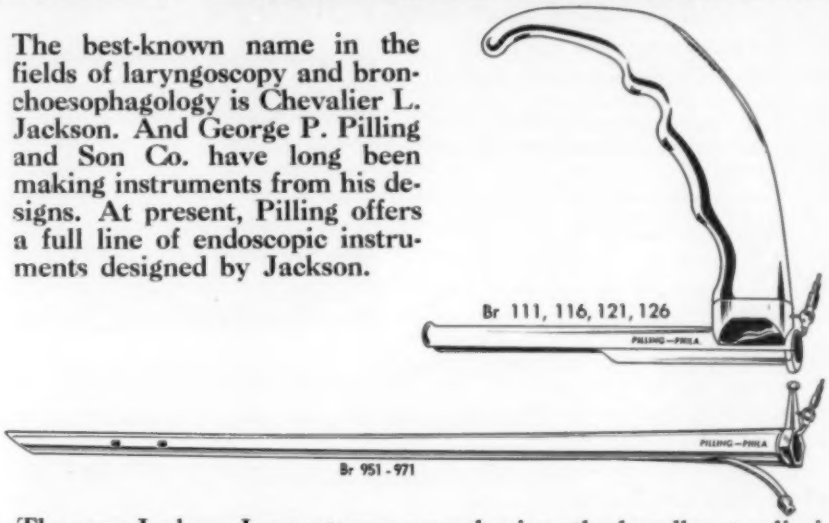

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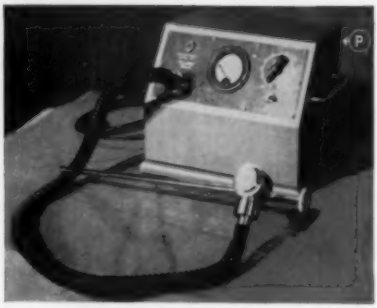

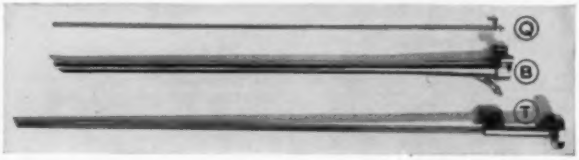

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Jackson, C.L.: New Instrumentarium for Peroral Endoscopy and Endoscopic Photography. LARYNGOSCOPE, *67*:777, (Aug.) 1957.

Fourestier, M., Gladu, A., and Vulmiere, J.: LA PRESSE MEDICALE, *60*:1292, (Oct.) 1952.

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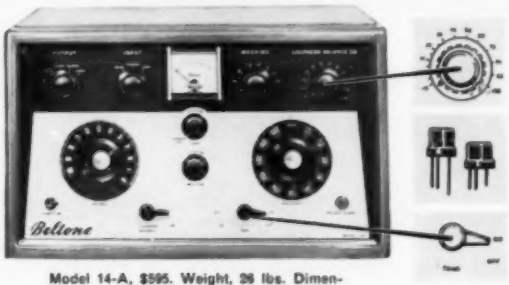

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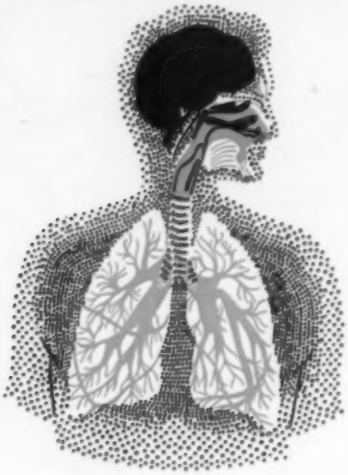

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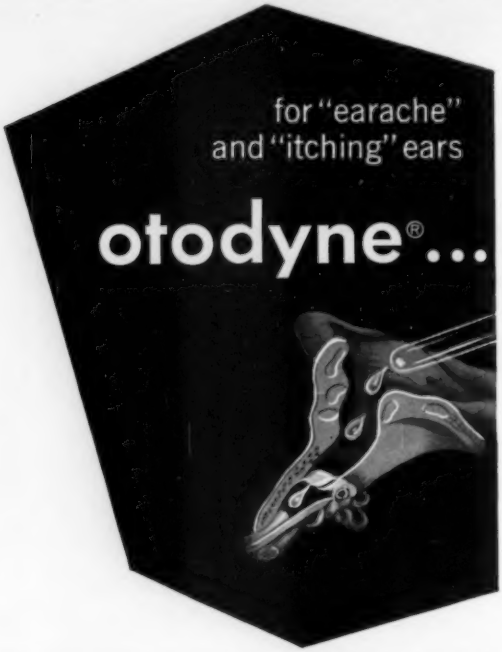

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Books and monographs received are acknowledged in this column. This notice may be regarded as a return courtesy to the publisher or author. Reviews will be published later as the editors may elect.

Notice of each book or monograph, including title, name of author, publisher, pagination, price, etc., will be presented in these notices so that our readers may have all data at their disposal for further inquiry.

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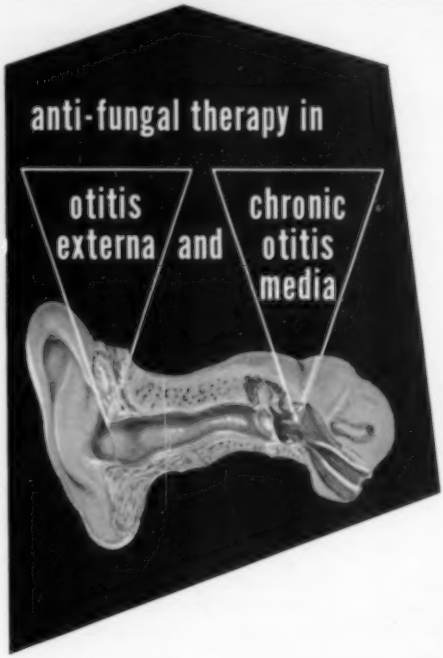

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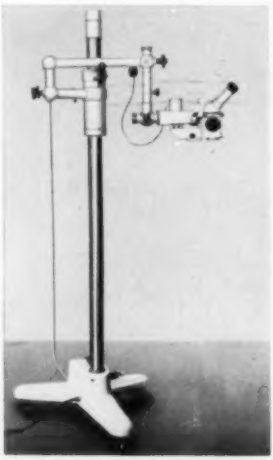

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3. Fox, S.L.: Clin. Med. 4:699 (June) 1957.

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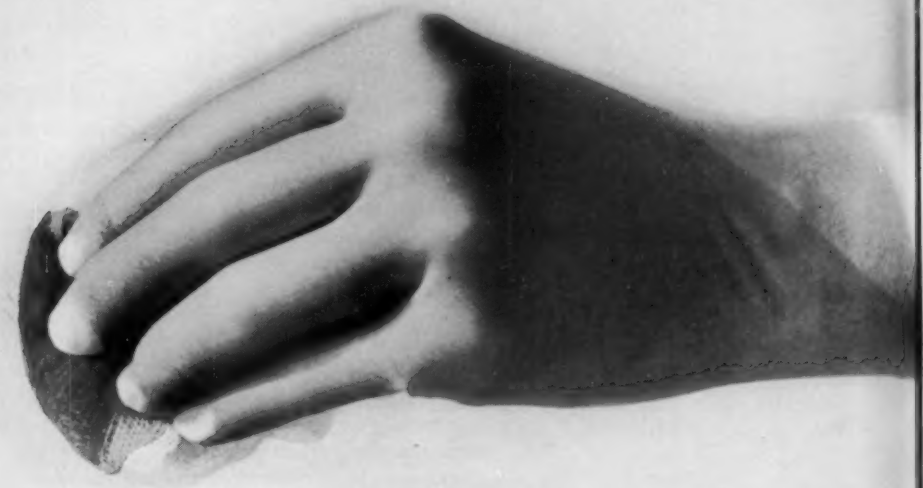

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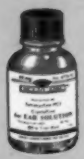

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INDEX OF ADVERTISERS

	Page
American Cyanamid Company	18
Beltone Audiometers	9
Books Received	12
Burroughs Wellcome & Co.	Inside Front Cover Also 11
Central Institute for the Deaf	21
Doho Chemical Corp.	8
Journal Laryngology and Otology	14
Maico	17
The S. E. Massengill Co.	3-4
Merck Sharp & Dohme	16
V. Mueller & Co.	13
F. Neuberger	20
Nichols Nasal Syphon, Inc.	19
Notice to Subscribers	Inside Back Cover
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INDEX ISSUE

VOLUME LXVIII DECEMBER, 1958 NUMBER 12

CONTENTS

RHINOMANOMETRY IN SOME RHINOLOGIC DISEASES. Joseph H. Ogura, M.D., and Poul Stokstead, M.D., St. Louis, Mo. - - - 2001

A STUDY OF THE RELATIONSHIP OF AIR PRESSURE TO MYRINGORUPTURE. A. Paul Keller, Jr., M.D., Athens, Ga. - - - - - - 2015

LARYNGOLOGIC EXPERIENCE IN BULBAR POLIOMYELITIS. Charles P. Lebo, M.D., San Francisco, Calif. - - - - - - - - - - - - 2030

STUDIES OF FACTORS CONSIDERED RESPONSIBLE FOR DISEASES OF THE EXTERNAL EAR. I. SURVIVAL OF EXOGENOUS BACTERIA IN THE EXTERNAL AUDITORY CANAL UNDER VARIED CONDITIONS. Ben H. Senturia, M.D., and Charles D. Carr, M.T., St. Louis, Mo. 2052

STUDIES OF FACTORS CONSIDERED RESPONSIBLE FOR DISEASES OF THE EXTERNAL AUDITORY CANAL. II. EVALUATION OF TEMPERATURE AND HUMIDITY AS THEY INFLUENCE THE AMOUNT OF ETHER-SOLUBLE SUBSTANCES IN THE EXTERNAL AUDITORY CANAL. Elizabeth S. Baumann, B.A., Carl F. Gessert, Ph.D., and Ben H. Senturia, M.D., St. Louis, Mo. - - - - - - - - - - - - - 2080

CONGENITAL BILATERAL COMPLETE BONY CHOANAL ATRESIA. Jack A. Rubin, M.D., Winnipeg, Manitoba - - - - - - - - - - - 2094

PROCAINE CONVULSIONS. John Keohane, M.D., Stettler, Alta, Canada 2096

ABSTRACT OF THE PROCEEDINGS OF THE SEVENTY-NINTH ANNUAL MEETING OF THE AMERICAN LARYNGOLOGICAL ASSOCIATION, San Francisco, Calif., May 19-20, 1958 - - - - - - - - - - 2098

IN MEMORIAM: CHEVALIER JACKSON, M.D., Sc.D., LL.D., L.H.D., F.A.C.S. - 2120

DIRECTORY OF OTOLARYNGOLOGIC SOCIETIES - - - - - - - - - - 2128

INDEX FOR THE YEAR 1958—SUBJECTS AND AUTHORS - - - - - - - I

7194